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DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

Research Note
No. 3

June 30, 1933

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U. S. FOREST SERVICE
CALIFORNIA FOREST EXPERIMENT STATION
Berkeley, California

PRODUCTION OF LUMBER, LATH, ~~AND SHINGLES~~ IN CALIFORNIA, 1932

This is a preliminary statement prepared by the Forest Service based on returns from the lumber census conducted for the Bureau of the Census by the Forest Service. Figures are subject to correction in final published report by the Bureau of the Census. Nevada is included to avoid disclosing individual production.

LUMBER CUT - M Ft. B.M.
(Mills cutting 50M or over)

SPECIES	PINE REGION (1)		REDWOOD REGION		TOTAL	
	Volume	%	Volume	%	Volume	%
Ponderosa pine	386,381	76.0	25	.0	386406	55.7
Sugar Pine	46,362	9.1	-	-	46,362	6.7
White fir	(2)26,072	5.1	3,535	2.1	29,605	4.3
Douglas fir	39,296	7.7	30,351	17.7	69,647	11.2
Cedar	(3)10,956	2.1	1,000	.6	11,956	1.7
Redwood	(4) 82	.0	135,448	79.2	135,530	19.6
Spruce	--	-	766	2.4	766	.8
Hemlock	--	-	--	-	--	--
TOTALS	(5)509,149	100.0	171,123	100.0	680,272	100.0

Foreign and domestic hardwoods	150
TOTAL, mills 50M and over	680,422
In addition to the above, 38 mills in California and Nevada producing less than 50 M each cut	775
TOTAL, all softwoods and hardwoods	681,197

Lath	7,944 M pcs.	1,449 M pcs.	9,393 M pcs.
Shingles	385 " "	16,617 " "	17,002 M pcs.

(1) Does not include northern part of commercial California pine region in southern Oregon.
(2) Includes both white and red fir.
(3) The pine region cedar cut was entirely incense cedar; that of the redwood region was all Port Orford cedar.
(4) Bigtree (*Sequoia washingtoniana*). The redwood of the (coast) redwood region is *Sequoia sempervirens*.
(5) About 9 million feet of Douglas fir was cut from Oregon logs.

Comparative production since 1920 - totals for all mills (California and Nevada) cutting over 50 M feet per annum including hardwoods:

Year	Cut M feet	Year	Cut M feet	Year	Cut M feet
1921	1,350,438	1925	2,042,991	1929	2,063,229
1922	1,720,556	1926	2,187,959	1930	1,514,263
1923	2,118,094	1927	2,070,811	1931	957,740
1924	1,996,496	1928	1,952,659		

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The cut for the State in 1932 was 277,318 M less than that of 1931 (mills cutting 50M and less being disregarded), and was 71.0% of the cut of that year and 44.9% of that of 1930. The pine region cut was 74.4% of that in 1931 and 49.7% of that of 1930. The redwood region cut was 62.5% of that for 1931 and 35.0% of that for 1930. As in former years, the redwood region was thus able under stress to reduce its cut further than was the pine region. There has been a small increase in small mills (cutting under 50 M ft. per year), from 31 mills cutting 712 M ft. b.m. in 1931 to 38 mills cutting 775 M ft. b.m. in 1932. This is considerably less of a small-mill increase, however, than has been supposed by many to have taken place.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

Research Note No. 12 October 2, 1936

THE UNIVERSITY OF THE SOUTH
SEWANEE TENN.

COMPARATIVE YIELD OF LUMBER GRADES FROM THREE GRADES OF REDWOOD LOGS CLASSIFIED ON THE BASIS OF THEIR SUPERFICIAL APPEARANCE IN THE STANDING TREE 1/

Research Note No. 8 issued by this Station on March 10, 1936, gave the results of a preliminary analysis of five redwood log grades which had been prepared for a tentative classification of logs in the standing tree prior to a sawmill production study in Humboldt County. Application of lumber selling prices to the yield of each log indicated that tentative Grade II needed revision and that Grade III could be consolidated with Grade IV. Further analysis has led to the following simplified three-grade classification:

Standing-tree log grades

These specifications apply to 16-foot log lengths.

Through-knots are indicated by single branches, sound branch stubs and recently healed-over knot holes in the bark.

Sap-knots are generally indicated by clusters of small branches radiating fanwise from usually bulging bases.

A cluster of two or more small knots which can be circumscribed by a circle 1 foot or less in diameter shall be counted as 1 knot.

GRADE I. Grade I logs smaller than 30 inches in diameter shall have no through-knots or sap-knots except within 1 foot of one end. Grade I logs larger than 30 inches may have through-knots and sap-knots within 1 foot of one or both ends and 1 through-knot in the central 14-foot zone. One large sap-knot, 2 medium sap-knots, or 3 small sap-knots are permitted in the central zone in addition to 1 through-knot. If no through-knot is visible, the sap-knot allowance in the central zone may be doubled, i.e., 2 large, 4 medium, or 6 small sap-knots, or equivalent combinations, such as 1 large and 3 small, or 1 large and 2 medium sap-knots. Logs with the maximum allowance of knots should be exceptionally smooth in appearance between knots to qualify as Grade I, otherwise they should be dropped to Grade II.

1/ By M. R. Brundage and T. J. Orr, Jr., Section of Forest Products.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

GRADE II. Logs with a clear length of 12 feet, measuring either from one end or between knots at both ends, or continuously clear from end to end for 75 percent of the circumference, shall be classed as Grade II regardless of the number of knots on the 4 feet of end zone or the 25 percent of knotty circumference.

Logs with scattered through-knots not confined entirely within feet of end zone or 25 percent of the circumference shall be classed as Grade II if the total number within the central 14-foot zone does not exceed 1 for each 10 inches of log diameter. Whether there should be a limit in number of sap-knots in Grade II logs cannot be determined from the data so far collected by this Station but apparently an allowance of at least twice the number specified for Grade I is permissible.

GRADE III. Logs with through-knots exceeding the limits for Grade II shall be classed as Grade III.

The average comparative yields of each green lumber grade, with no allowance for degrade and footage losses between green chain and shipment, are shown in table 1 as percentages of total green tally, #3 Common and Better, for various sizes of logs graded according to the above rules. Comparisons of green lumber tally with gross Spaulding scale and with Humboldt scale appear in the last two columns. The data have been adjusted by curving the actual lumber production from 550 study logs cut in a Humboldt County sawmill in 1935. It should be mentioned that the logs observed were free from the usual pre-logging fire damage since the study plot was not burned over between log-peeling and yarding. Additional studies of about 100 logs made in another Humboldt County mill this year are now being analyzed in conjunction with the 1935 study for the formulation of grading rules applicable to bucked logs before and after peeling. Rift crack, spiral grain, birdseye, spot rot, compression wood, and other defects which cannot be taken into account in standing-tree log grading will be included in the bucked log specifications.

Since internal defects often affect the quality of lumber produced o a greater extent than defects visible on the bark surface, it is inevitable that there will be considerable deviation above and below the curved averages in the yields from individual redwood logs classified only on the basis of surface appearance in the standing tree. From this it follows that the yields from individual trees cannot be predicted with a high degree of accuracy. Nevertheless standing-tree log grades are sufficiently dependable with respect to the prediction of average yields to make them of real value in appraising different units of timber and in determining the approximate comparative realization values obtainable from different classes of trees in the same stand.

The relation of average FOB-mill green-lumber selling value to log diameter is shown for each of the three log grades in figure 1. These curves were derived by application of rough green-lumber selling prices listed as of May 18, 1936, to the curved grade production data in table 1. Discounts for quantity shipments and freight to the Bay Region have been deducted.

Table 1.-Production of green lumber grades in percent of total green-chain tally from average redwood logs of different sizes and log grades and percent of difference between log scale and green-chain tally of #3 Common and Better lumber.

Log grades based on surface appearance in the standing tree. Mill run sound and defective logs from a study plot in Humboldt County, 1935. Medium quality stand.

Log diam. small end	LUMBER GRADES[1]							Lumber Tally under(-)or over(+)	
	Selects			Common					
	Clear Heart	A Grade	B Grade	#1	#2	#3	Shop	gross scale[2]	Humboldt scale
Inches	LOG GRADE I								
20	2.2[3]	9.0	18.1	19.7	21.0	29.7	0.3[3]	-26.0	+ 5.7
25	3.5	9.6	18.3	21.3	19.4	27.5	0.4	-26.0	+ 5.7
30	5.0	10.7	18.5	22.6	17.5	25.2	0.5	-26.5	+ 5.0
35	7.5	11.7	18.0	24.0	15.8	22.3	0.7	-27.3	+ 3.9
40	10.3	13.2	16.9	25.9	13.2	19.6	0.9	-28.5	+ 2.1
45	13.1	15.4	15.5	27.3	11.2	16.2	1.3	-30.0	0.0
50	16.0	17.5	13.3	28.6	10.0	13.2	1.4	-32.0	- 2.9
55	19.0	18.0	11.8	29.6	9.0	11.2	1.4	-33.1	- 4.4
60	21.5	18.0	11.0	30.7	8.5	9.0	1.3	-34.0	- 5.7
65	23.5	18.0	10.5	31.7	8.0	7.2	1.1	-34.7	- 6.7
70	25.0	17.8	10.0	32.6	7.7	6.1	0.8	-35.1	- 7.3
75	26.1	17.4	9.5	33.4	7.5	5.6	0.5	-35.5	- 7.9
80	27.2	17.0	9.3	34.0	7.5	4.7	0.3	-35.9	- 8.4
85	28.3	16.3	9.2	35.0	7.5	3.5	0.2	-36.3	- 9.0
90	29.2	15.8	9.0	35.7	7.5	2.7	0.1	-36.6	- 9.4
	LOG GRADE II								
20	1.0	3.2	13.0	13.8	19.5	49.0	0.5	-18.0	+17.1
25	1.5	4.7	13.5	15.0	17.5	45.5	2.3	-20.7	+13.3
30	2.2	7.2	14.2	15.8	15.4	41.7	3.5	-23.3	+ 9.6
35	4.0	10.2	14.8	16.2	13.5	36.6	4.7	-25.8	+ 6.0
40	7.2	13.5	15.1	16.5	11.7	31.1	4.9	-28.0	+ 2.9
45	10.0	16.3	15.4	16.8	11.0	25.5	5.0	-30.0	0.0
50	12.3	17.1	15.8	17.5	10.2	21.8	5.3	-32.0	- 2.9
55	14.0	17.5	16.0	18.8	9.7	18.3	5.7	-33.1	- 4.4
60	15.3	17.0	16.0	20.4	9.2	16.6	5.5	-34.0	- 5.7
65	16.5	16.0	16.2	22.5	9.0	14.8	5.0	-34.7	- 6.7
70	17.3	15.0	16.7	24.6	8.9	13.2	4.3	-35.1	- 7.3
75	18.0	14.0	17.2	27.2	8.8	11.6	3.2	-35.5	- 7.9
80	18.5	13.0	17.7	29.8	8.7	10.3	2.0	-35.9	- 8.4
	LOG GRADE III								
20	0.5	3.7	13.0	9.5	9.5	56.8	7.0	-13.8	+23.1
25	1.0	4.4	13.1	9.6	11.0	55.4	5.5	-18.0	+17.1
30	1.9	5.2	13.2	9.7	12.0	53.2	4.8	-21.8	+11.7
35	2.8	6.2	13.3	10.0	12.5	50.3	4.9	-25.0	+ 7.1
40	3.6	7.4	13.5	10.9	12.5	46.3	5.8	-28.1	+ 3.0
45	4.0	8.6	13.5	13.0	12.2	41.3	7.4	-30.0	0.0
50	4.5	10.3	13.5	16.2	11.5	34.8	9.2	-32.0	- 2.9
55	4.6	12.2	13.5	20.3	10.5	28.7	10.2	-33.1	- 4.4
60	4.9	14.4	13.4	23.6	9.5	23.9	10.3	-34.0	- 5.7
65	5.0	16.8	13.2	26.7	8.5	19.8	10.0	-34.7	- 6.7
70	5.0	19.4	13.0	29.3	7.5	16.8	9.0	-35.1	- 7.3

[1] Timbers are included with lumber grades of equivalent value.

[2] Gross scale, Spaulding rule.

[3] Figures from Clear to Shop, inclusive, total 100 percent across page for each diameter class.

The curves for log grades I and II may be said to represent "tree-run" averages, but that for grade III represents only the better of the low quality logs. The "tree-run" of grade III logs would be worth less than the curved values since it would include the very rough top logs which are seldom utilized in actual practice. The majority of grade II logs which reached the mill during the study had only a few knots in excess of the limits for grade II. Another grade, No. IV, appears to be desirable for a better division of the lower quality logs. In a four-grade classification, grade III could permit, say, twice as many knots as grade II, or 1 through-knot for each 5 inches of log diameter. There would be too great a range in the selling values of grade III logs as defined above if all logs in the upper third of large trees were to be included in a study run. From the standpoint of distinguishing between profitable and unprofitable rough logs after a tree is down, a finer division of the lower grades will be very helpful.

The two study logs of lowest average selling value were a 37-inch log worth $15.26 and a 49-inch log worth $15.18 per M B.M. green-chain tally. The two of highest value were a 49-inch log worth $55.06 and a 75-inch log worth $54.05 per M B.M. green-chain tally.

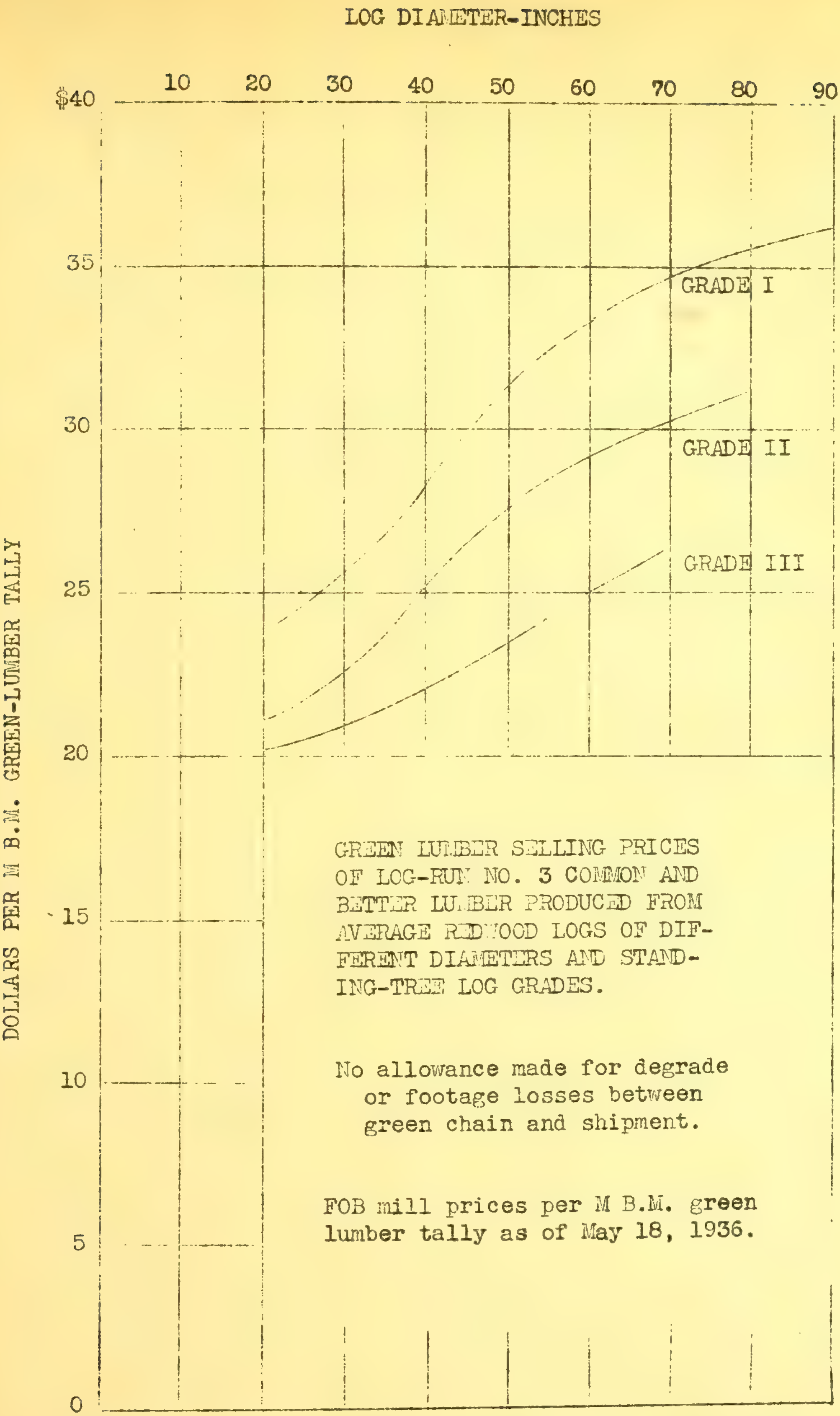
Average selling values of the lumber from logs of each 10-inch diameter class, read from the curves in figure 1, are as follows:

Log grade	Log diameter, inches 20	30	40	50	60	70	80	90
	Dollars per M B.M. green-chain tally							
I	23.85	25.67	28.31	31.52	33.35	34.70	35.58	36.14
II	21.20	22.60	25.35	27.67	29.12	30.25	31.22	
III	20.05	20.85	21.95	23.38	24.98	26.30		

The production of each lumber grade from the study-run of each log grade as a whole is shown below:

Log grade	Diam. avg. log	Clear Heart	A Grade	B Grade	#1 Common	#2 Common	#3 Common	Shop	Total
	Inches	Percent							
I	56	18.2	16.9	13.3	30.2	10.1	10.3	1.0	100.0
II	49	11.0	15.2	14.7	19.8	12.2	22.2	4.9	100.0
III	43	3.7	9.8	13.0	15.0	10.9	40.8	6.8	100.0

The quality of yield from redwood logs undoubtedly varies with density of stand, type of soil, local climate, exposure, and other local differences, entirely apart from its variation as related to log size and log grade. This is true of logs in the California pine and other regions where several studies have been conducted in different localities and there are no good reasons to assume that the redwood region is any exception. More studies are needed to determine the approximate extent of such variability. The data herein represent a quality of timber probably intermediate between that of the dense virgin stands found on flats and that of more open stands growing on slopes at the higher elevations.



GREEN LUMBER SELLING PRICES OF LOG-RUN NO. 3 COMMON AND BETTER LUMBER PRODUCED FROM AVERAGE REDWOOD LOGS OF DIFFERENT DIAMETERS AND STANDING-TREE LOG GRADES.

No allowance made for degrade or footage losses between green chain and shipment.

FOB mill prices per M B.M. green lumber tally as of May 18, 1936.

Figure 1.- Comparative selling values per M B.M. green lumber tally of various sizes and grades of redwood logs,-green-chain grade basis.

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN

Research Note No. 14 January 20, 1937

AN INFILTRATION STUDY
OF A DENUDED AND A FOREST COVERED SOIL[1]

One of the important functions of the forest in relation to run-off and erosion is that of developing and maintaining soil permeability. This in turn materially increases the absorption or infiltration capacity of a soil for precipitation. The extent of this influence of the forest cover is demonstrated by a series of infiltration tests made at Kennett, California, on smelter fume denuded and adjacent forested soils.

In 1905 both soils were the same. They supported a vegetation similar to that now found on the forested soil and possessed like chemical and physical properties. In that year a smelter was established and by 1910 the toxic effect of the smelter fumes had completely destroyed the forest growth on 67,000 acres and had severely damaged the vegetation on an additional 86,000 acres. Although operation of the smelter was later discontinued, vegetation has never reclaimed the area.

The Kennett soils, developed under a temperate climate with an average annual precipitation of 59.3 inches, are immature, red, rocky, gravelly clay loams formed *in situ* from undifferentiated metamorphosed limestones, slates, and quartzites. They normally support an open, brushy Douglas fir - ponderosa pine vegetative type of sufficient density when undisturbed to afford adequate protection against erosion and flood hazards.

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[1] By P. B. Rowe, Associate Silviculturist, D. M. Ilch, Assistant Silviculturist, and René Bollaert, Junior Forester.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

In determining differences in the infiltration capacities of the soils a modification of the Auten tube method[2] was used. This method employs a brass tube 2 inches in diameter and 12 inches long which when a test is to be made is placed into the soil to a depth of 3 centimeters. It is then filled with water which is held at a constant head during the run. The volume of water required to maintain the water level is measured as it is added to the tube and recorded at 5-minute intervals. A comparison of the rates at which water is absorbed yields an empirical measure of the differences in the infiltration capacity of the soils sampled.

Fifteen infiltration tests were made at Kennett, 8 on the denuded soil and 7 on the adjacent forested areas. The duration of the individual runs averaged approximately 20 minutes, totaling 295 minutes. The small number of runs and the rocky texture of the soil resulted in a high experimental error. However, analysis of the data shows the differences in the infiltration rates of the forested and denuded areas to be so great as to be highly significant.[3] That is, were other tests to be made similar differences would be expected in more than 99 percent of the trials.

Results of the tests show that the quantity of water entering both covered and denuded soils decreased rapidly during the first 15 minutes of infiltration, becoming more or less constant during the following 10 minutes. The rapid absorption at the start of the runs was largely due to the original dryness of the soil and to disturbances in placing the tube. Although the forested soil appeared to be the slower in reaching a constant infiltration rate the soils sampled were not significantly different in this respect.

Average infiltration rates presented quite a different story, varying greatly with differences in the surface conditions of the soil sampled. Infiltration was slowest on denuded soil having a heavy erosion pavement with its almost impervious top layer. Where surface run-off had occurred at intensities sufficient to remove the erosion pavement, the infiltration capacity of the soil was slightly increased. The lowest infiltration rate recorded for the forested soil was more than double the highest rate on the denuded soil. The lowest rate on forested soil was for those portions that had been partially affected by smelter fumes; the highest occurred under the less disturbed stands with a fully developed litter cover.

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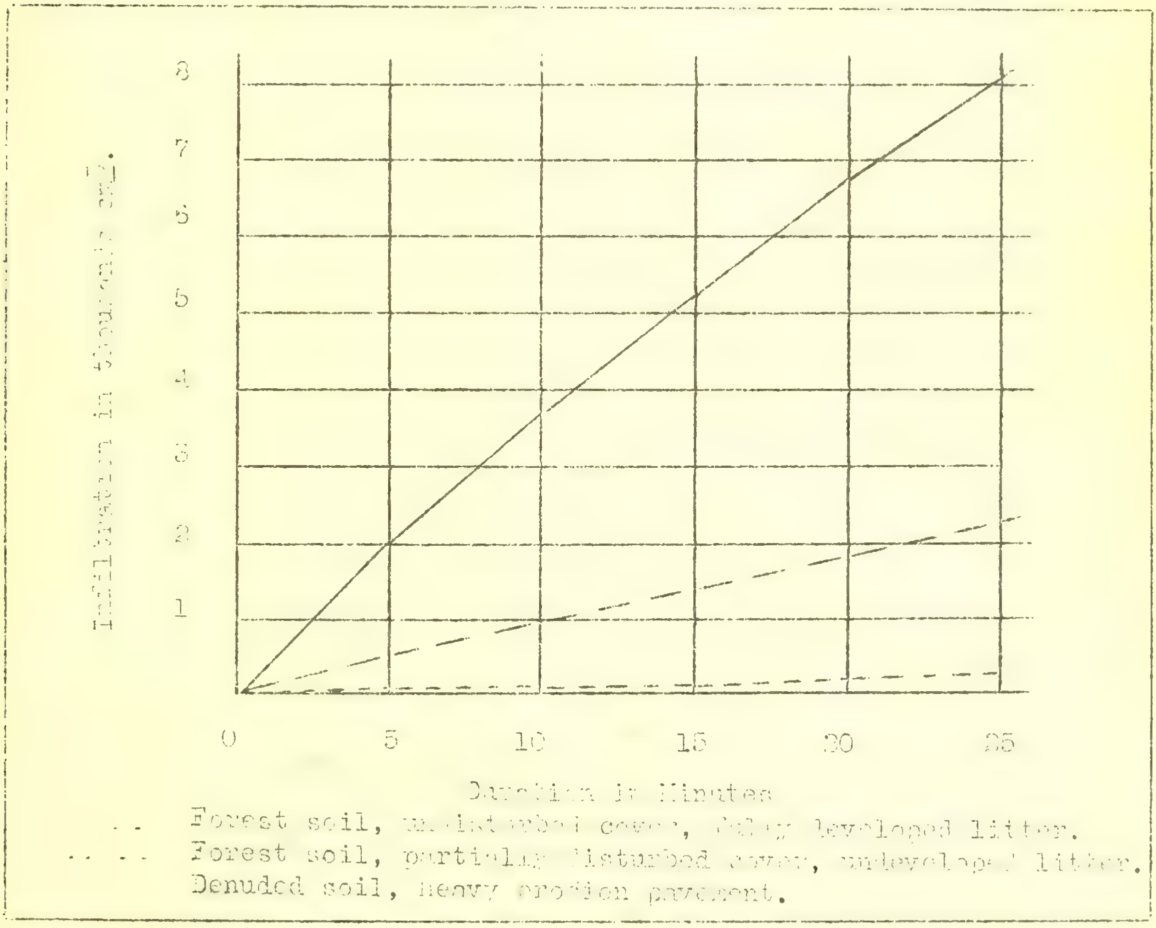
[2] Auten, J. T. June 1933. Porosity and water absorption of forest soils. Journal of Agricultural Research 46:11, 997-1014.

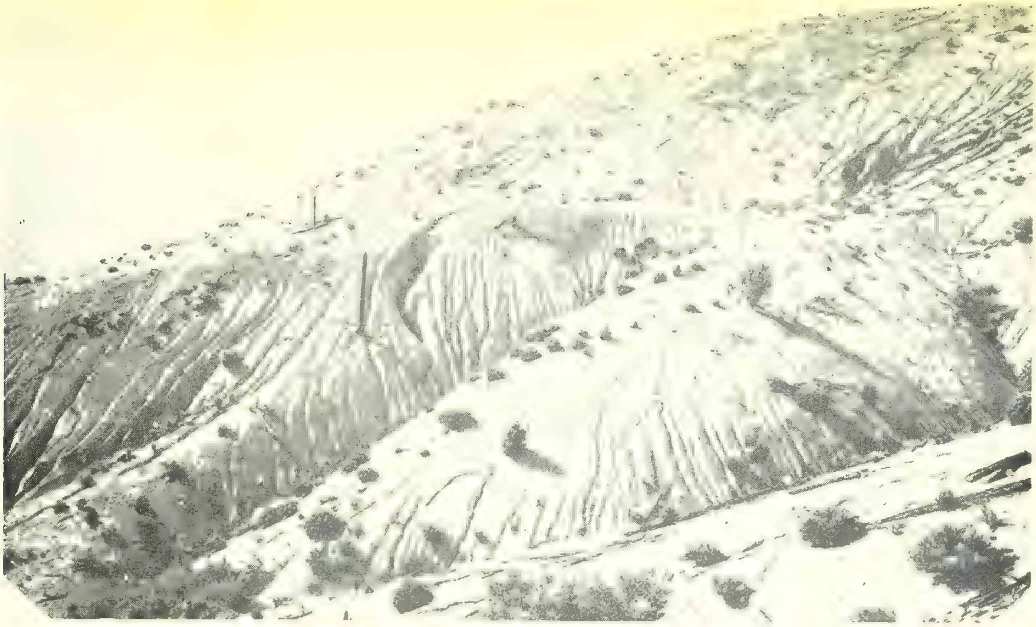
[3] Snedecor, George W. 1934. Calculation and interpretation of analysis of variance and covariance. Ames, Iowa: Collegiate Press, Inc.

Numerically, the infiltration for the denuded soils tested was at an average rate of 23.5 cm^3 per minute with a range of 9.8 to 41.2 cm^3. For forested soils the infiltration ranged from 90.4 to 321.0 cm^3 per minute, averaging 263.7 cm^3. Thus the forested soil absorbed 2.2 to 32.8 times or an average of 13.2 times as much water in a given interval as did the denuded soil.

Inasmuch as these two soils were the same some twenty-six years ago it may be concluded (1) that the vast differences in their present infiltration capacities are largely due to the influence of forest cover; (2) that the destruction of the forest has impaired the ability of the denuded soil to absorb precipitation, resulting in accelerated surface run-off and erosion and finally complete devastation of the area.



Typical infiltration runs showing the influence of vegetation in maintaining the soil permeability.



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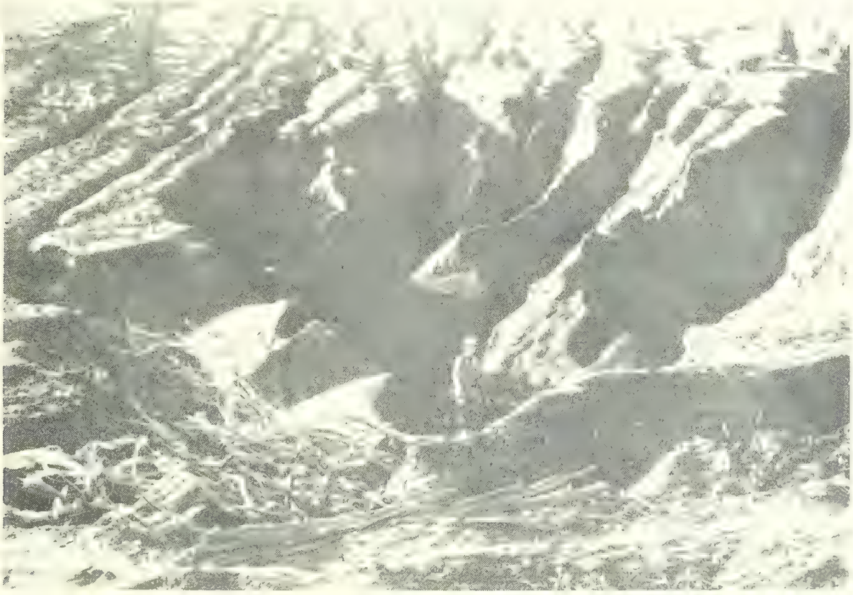
A portion of the Kennett smelter fume denuded area as it appeared in 1935. Erosion pavement covers most of the soil where gullies have not cut it away. The sparse vegetation that is becoming established has as yet no influence in controlling surface run-off and erosion.



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This close-up of the gullies appearing in the upper right hand corner of the first photograph gives an idea of the quantity of material removed in the 25 years since the area was denuded.

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IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA
BERKELEY

Research Note No. 15. June 4, 1937

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THE UNIVERSITY OF THE SOUTH
SEWANEE TENN.

COMPARATIVE COSTS FOR SLACKLINE, HIGHLEAD AND TRACTOR YARDING

REDWOOD REGION

by
Hubert L. Person, Silviculturist

Tractors have been used for the past 10 years as supplementary yarding equipment in the redwoods, but it was not until about 1935 that they could be considered as serious competitors of the slackline and highlead methods which have been favored by redwood loggers during the last 15 or 20 years. This change in status was the result of marked improvement in the tractors themselves and to an even greater extent to their auxiliary equipment - the yarding arches, single and double hoists and bulldozers, angle dozers and trail builders. By means of this improved equipment the yarding of the largest log that could be handled at the sawmill was made practicable even on steep, rough slopes and the tractor was ready to come into its own.

The success of the tractor in parts of the coastal Douglas fir region of Oregon and Washington, where conditions were not greatly different from those found in much of the redwood region, together with public pressure for less destructive woods practices, provided the necessary incentive and redwood operators, to their credit, undertook to give them a trial. And because of the many advantages inherent in highly flexible equipment, and the possibilities offered through selective logging for greater profits and the saving of unmerchantable trees and reproduction, the California Forest and Range Experiment Station undertook a regional yarding study in cooperation with the redwood operators to compare the efficiency of this new tool with the generally used steam equipment.

The purpose of the yarding study was:

1. To compare the efficiency and cost of tractor, slackline and highlead yarding; and

2. To determine the effect of log size and certain other factors on yarding costs for the three methods studied.

The field work was begun in 1934 and completed in 1936. Completion was delayed because of the introduction in 1934 of new Diesel equipment which resulted in the virtual obsolescence of the old gasoline tractors. In the course of the study yarding time and cost data were obtained from 3 slackline, 6 highlead and 12 tractor settings, including a total of 8,538 trips with 18,600 logs scaling [illegible],545,000 ft. B.M.

This report is based on three slackline, three highlead and three tractor settings, all from Humboldt County. They were selected from the settings studied on the basis of similarity of conditions as to volume of stand per acre, and steepness and roughness of topography. Neither the lowest nor highest cost tractor settings were included, and all conditions affecting costs are believed to be at least as favorable on the steam as on the tractor settings. The settings selected were on the operations of three different companies each of which contributed to both steam and tractor data.

Methods

The results are based on:

1. Accurate timing of each activity involved in yarding, such as in and out time, hook and unhook time, all delay items, etc.

2. Careful measurements of diameter and length and determination of cull and gross and net scale for each log.

3. Cost per hour and per minute of each yarding unit for each setting. A tractor arch and drum combination is considered a unit.

The timing and scaling give the basis for determining the volume of logs yarded by each machine. By applying the per minute cost of a yarding unit to the output of that unit the actual cost per M. bd. ft. of log scale was determined.

The data were also analyzed to show the effect of log size, load volume, yarding distance, and slope (for tractor yarding) on yarding cost.

The itemized costs used as the basis of comparison are listed in table 1.

Table 1.- Cost items included in the total yarding cost per hour and per M for tractor, slackline and highlead. Humboldt Scale.

Cost items	Yarding method					
	Tractor1/		Slackline2/		Highlead3/	
	Cost - Dollars		Cost - Dollars		Cost - Dollars	
	Per hour	Per M	Per hour	Per M	Per hour	Per M
1. Labor (including industrial insurance)	2.281	0.342	8.069	0.484	5.558	0.626
2. Fuel (wood and fuel oil for steam. Diesel oil and starting gas for tractors)	0.274	0.041	3.033	0.177	2.582	.310
3. Lubrication (oil and grease)	0.128	0.019	0.333	0.020	0.145	0.016
4. Wire rope	0.915	0.136	4.535	0.271	1.245	0.137
5. Rigging supplies, powder and misc.	0.153	0.025	1.665	0.100	0.727	0.080
6. Maintenance and repairs (including lubrication labor)	1.000	0.150	4.993	0.300	1.318	0.200
7. Uninsured risks (5 percent of average value)	0.221	0.033	0.245	0.015	0.132	0.014
8. Depreciation	1.470	0.221	0.272	0.016	0.146	0.016
9. Interest, taxes and insurance	.375	0.055	0.490	0.029	0.264	0.029
10. Rigging ahead, or road building for tractors	.906	0.110	3.342	0.201	1.368	0.201
Total yarding cost	7.784	1.131	27.177	1.613	14.485	1.629

1/ Average of 3 tractor settings - 1 Diesel and 2 semi-Diesel

2/ Average of 3 slackline settings

3/ Average of 3 highlead settings

Of principal interest are the nearly identical total cost per M feet for the slackline and highlead and the much lower cost for the tractors, nearly [illegible] cents lower per M feet.

The per hour costs are of little significance for comparison because of the wide variation in output per hour for the different machines.

Effect of Log Size and Yarding Distance on Yarding Cost

Yarding costs per M feet are consistently higher for small logs than for large logs. This is because the scale or board foot content increases faster with size than the cubic content and weight, and because it is easier to handle a given scale in one log if not excessively large, than to handle the same volume in several logs. For example, it is obviously cheaper to handle one log containing 5,000 bd. ft. than 10 logs each containing only 500 bd. ft. although the total scale is the same in both cases. A principal reason for this is that several of the time items - out-time, turning-time (for tractors), and most delay items - bear no relation to log or load-size; and other items - principally hook-and-unhook time - are only slightly affected by log size. Consequently, a large part of the round trip time involved in yarding is not affected by either load or log size and the larger the load or the log (within practicable limits) the smaller the amount of time and cost chargeable to each M feet of scale.

This decrease in cost per M feet with increase in log scale is shown graphically for all three yarding methods in figure 1 and for tractors and slackline in figure 2. Figure 1 is based on an external yarding distance of 1,000 feet and figure 2 on 2,000 feet. High lead yarding costs are not included in figure 2 because this method is not used for yarding much over 1,000 feet.

It should be noted that gross Spaulding scale is used, rather than Humboldt scale, in these charts. Also that rigging ahead, line changing and road building (for tractors) are not included in the costs given. As this combined item is higher for steam yarding than for tractor yarding in practically all cases the inclusion of this additional cost would make the difference in favor of tractor yarding even greater. Various overhead items, and other fixed per-acre costs which would not vary appreciably with the different methods are likewise omitted.

Both figures show that tractor yarding is cheaper than steam logging for all log sizes and for both external yarding distances. The greatest difference in favor of tractor yarding is in the small log sizes, the 500-foot log being nearly 80 cents cheaper per M with the tractor. But it is of interest that the tractor also shows up to advantage with the largest log sizes, because only a few years ago many redwood operators believed that tractors could not handle large logs efficiently. The consistently good showing of the tractor is the more

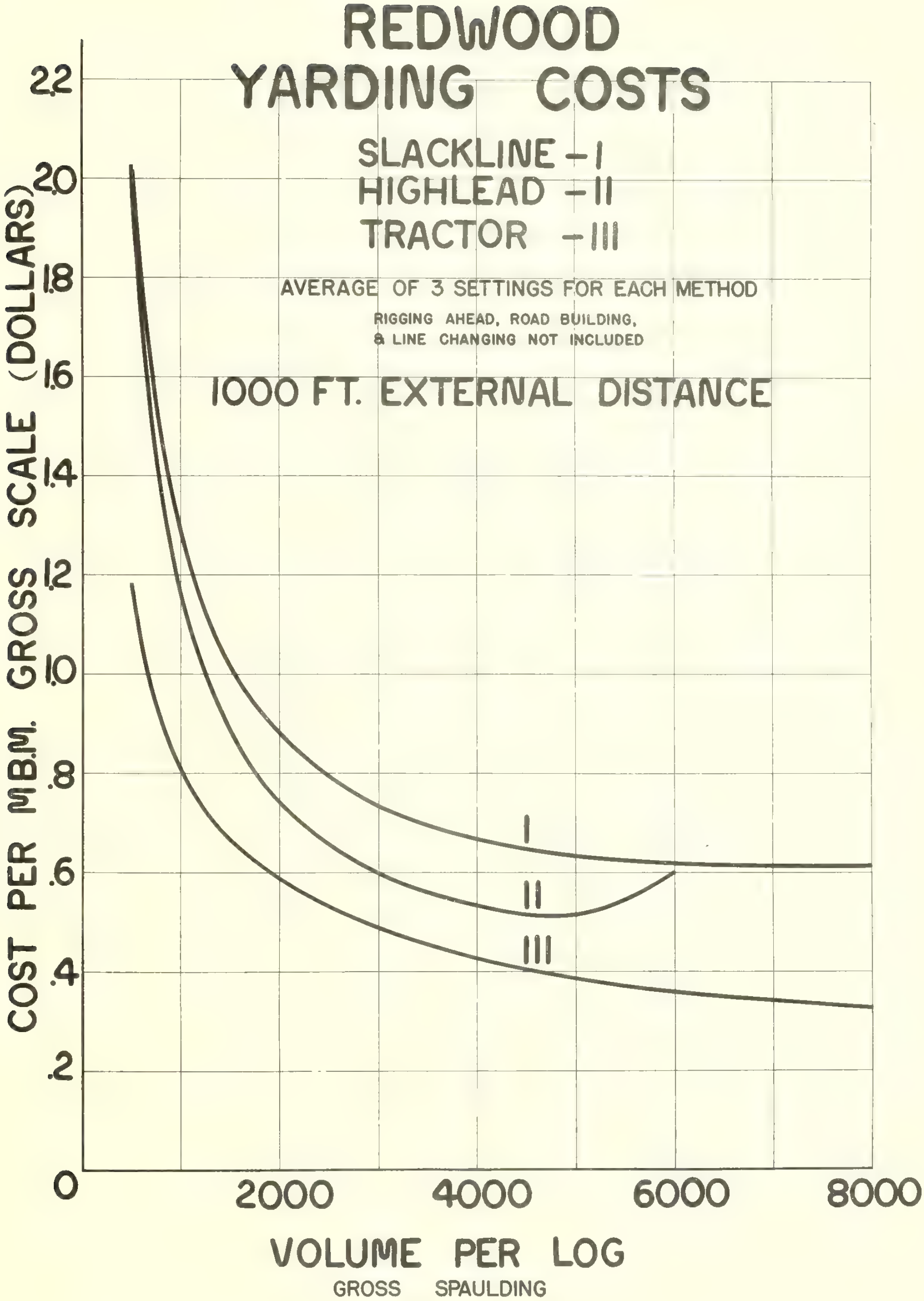REDWOOD
YARDING COSTS
SLACKLINE - I
HIGHLEAD - II
TRACTOR - III
AVERAGE OF 3 SETTINGS FOR EACH METHOD
RIGGING AHEAD, ROAD BUILDING,
& LINE CHANGING NOT INCLUDED
1000 FT. EXTERNAL DISTANCE
COST PER M.B.M. GROSS SCALE (DOLLARS)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
2000
4000
6000
8000
VOLUME PER LOG
GROSS SPAULDING
I
II
III

Figure 1

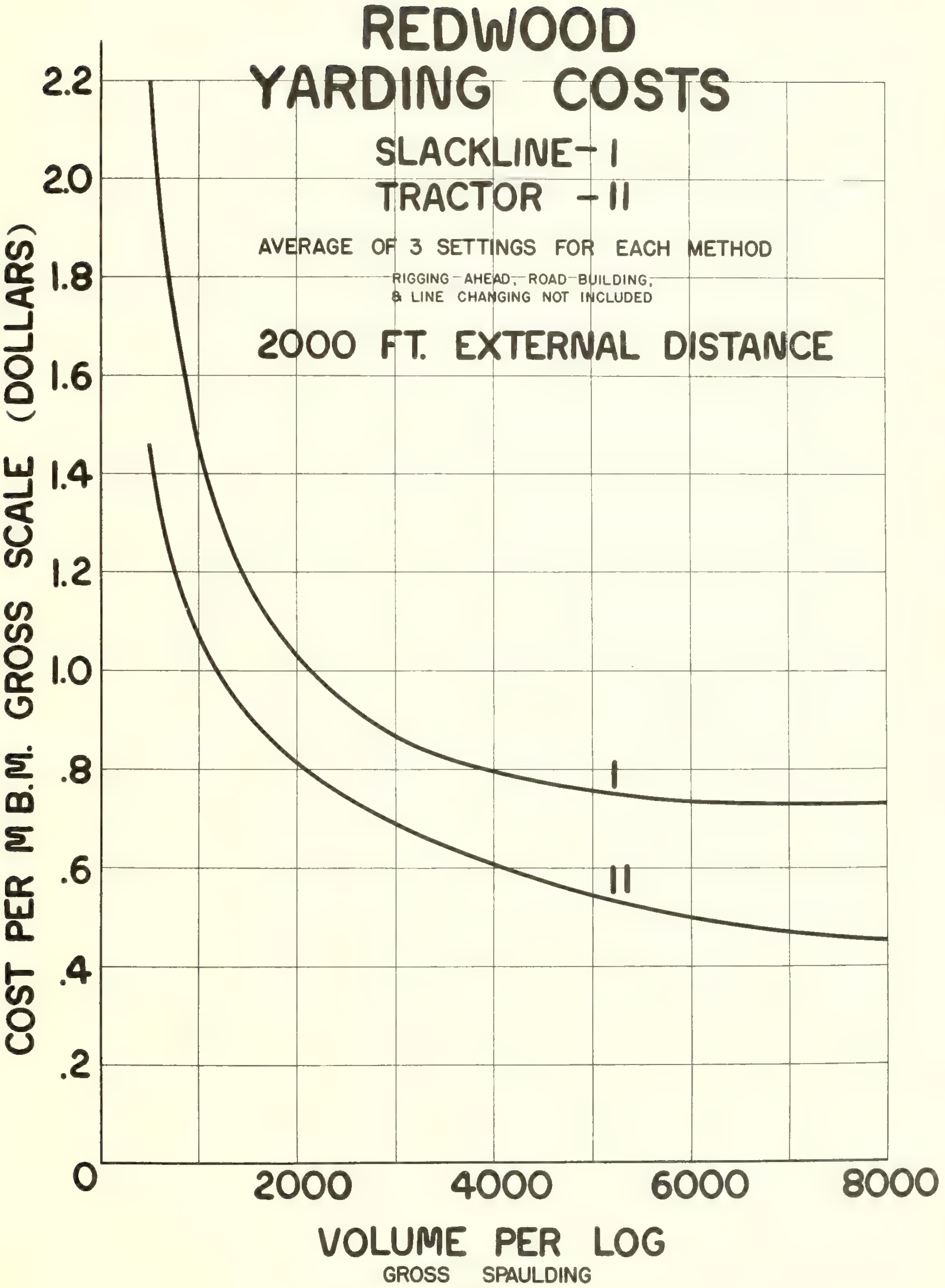
REDWOOD
YARDING COSTS
SLACKLINE - I
TRACTOR - II
AVERAGE OF 3 SETTINGS FOR EACH METHOD
RIGGING AHEAD, ROAD BUILDING, & LINE CHANGING NOT INCLUDED
2000 FT. EXTERNAL DISTANCE
COST PER M B.M. GROSS SCALE (DOLLARS)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
2000
4000
6000
8000
I
II
VOLUME PER LOG
GROSS SPAULDING

Figure 2

remarkable because it is a relatively new yarding method in the redwood region and still subject to many improvements whereas steam equipment has been used for years and slackline yarding in particular has been developed to a very high point of efficiency.

The difference between tractor and slackline costs with a 2,000-ft. yarding distance is seen to be somewhat smaller than with the 1,000-ft. distance. It should be emphasized, however, that the tractor is much more adaptable, and consequently has a great advantage wherever wide differences in distance are encountered. Both slackline and high lead machines are limited by certain maximum distances beyond which they cannot go and with them the long corner means the additional cost of a "swing". The tractor on the other hand has no such definite limitations and can be used with equal advantage for short and for long hauls up to the point where railroad or truck transportation may compete.

No attempt will be made here to discuss the many other advantages in tractor yarding resulting from the great flexibility of the tractor units. Their superiority in selective logging and the opportunities which they offer for maintaining a steady flow of logs in spite of differences in yarding distance, volume per acre and other conditions; in keeping the various parts of an operation well balanced and in solving many management problems such as filling special orders on short notice, should at least be mentioned.

The material presented in the foregoing is based entirely on summer, or dry weather, logging for both tractor and steam equipment. Tractors are obviously at a disadvantage on wet ground, particularly where clay soils are encountered. This is a serious difficulty for operators wishing to yard entirely with tractors. In some cases seasonal yarding operation has been found practical and in others attempts are being made to use the tractors through the winter by more careful road location and by frequent changes from road to road and from landing to landing. There are also many possibilities for winter use of tractors with doubledrum for short-distance line yarding and also in combination with Diesel yarders and other less mobile equipment.

In conclusion, it has been demonstrated that tractor yarding is superior to the conventional highlead and slackline yarding under most conditions found in the redwood region, except during the rainy season, and its much wider use is undoubtedly justified. The application of the ingenuity displayed by redwood loggers in the development of steam logging will undoubtedly solve many of the difficulties now encountered in winter tractor logging and make possible the elimination of much of the destruction of unmerchantable trees associated with slackline and to a less extent with highlead yarding.

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

BERKELEY

[illegible]
THE UNIV[illegible]
[illegible]

Research Note No. 16 June 4, 1937

REDWOOD TRACTOR YARDING COSTS AS AFFECTED BY SLOPE GRADIENT AND LOAD VOLUME

William Hallin, Assistant Silviculturist

Realization of the importance of planning in logging is essential to maximum efficiency. In tractor yarding day to day and log to log planning is of far greater importance than in steam yarding because each log may be taken out in many possible load combinations, often over any one of several possible routes, and in almost any order; whereas in steam yarding once the landing is rigged up the order is quite definitely established. This importance of short time planning on the ground as the logs are removed makes very close supervision essential in tractor logging. The hook tender (or side boss) must spend much of his time right where the loads are made up.

Basic data on most efficient slope gradients and most efficient load size, which are essential to proper planning, have been determined by time studies completed in the redwood region.[1]

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[1] See Research Note No. 15. Comparative costs for slackline, highlead and tractor yarding. H. L. Person.

Slope Gradient

For 75 to 95 horsepower tractors the average optimum out-and-in time per 100 feet horizontal distance occurs for 2000 foot loads (gross scale Spaulding) at 5 percent slopes, for 5000 foot loads at 7 percent slopes, and for 8000 foot loads at 15 percent slopes (see figure 1). These figures apply chiefly to a timber body where it is possible to locate the bunching point so as to give optimum slope with approximately the same tractor haul distance. All results of a study of this kind are essentially averages; consequently some of the heavier logs take more time than shown. With very large logs difficulties may be encountered on slopes of less than 5 percent which will increase the time much beyond the average shown in figure 1. Adverse grades and even favorable grades under 5 percent should, therefore, be avoided if at all possible. This applies equally as well to the short stretch coming into and crossing the landing. On most settings the usual practice is to have this stretch quite flat, and on the settings studied considerable lost time occurred in bringing the larger loads across the landing. A minimum slope of 10 percent would give a better margin for keeping heavy loads moving. It might not, however, give the most efficient results when other conditions controlled the set-up.

The most efficient slope for gaining a given difference in elevation is 30 to 31 percent, depending on the load volume, but for practical purposes it lies between 25 and 35 percent. (see figure 2). Although there are not sufficient data to give a reliable curve for slopes over 35 percent, general observations during the time studies and by various operators indicate that the maximum adverse slope over which 75 to 95 horsepower tractors and arches can go empty lies between 40 and 45 percent. What little data we have on slopes over 40 percent indicates that the in-time on slopes over 40 percent increases very rapidly. Consequently the maximum slope should be very little over 40 percent. Commonly topography and location of timber determine more or less definite points between which the sections of the road or roads must be built. The difference in elevation between two points is constant, but the horizontal road distance decreases as slope increases; consequently the most efficient slope is the 25 to 35 percent which is best for gaining the elevation. If the ground is not steep enough to allow 25 to 35 percent grades the most efficient grade would be the steepest possible grade between the two points, which in turn means that if the slope is constant and less than 35 percent a straight line will give the most efficient grade. If the slope between two points is less than 30 percent but quite variable, a longer route with a more constant slope may be better than a straight line; but this can only be decided on the ground in each individual case when the ground conditions for the alternative routes are known. As the most efficient slope gradient for gaining a given difference in elevation is the same for both in and out trips, the same principles would apply, even if separate roads are used for in and out travel.

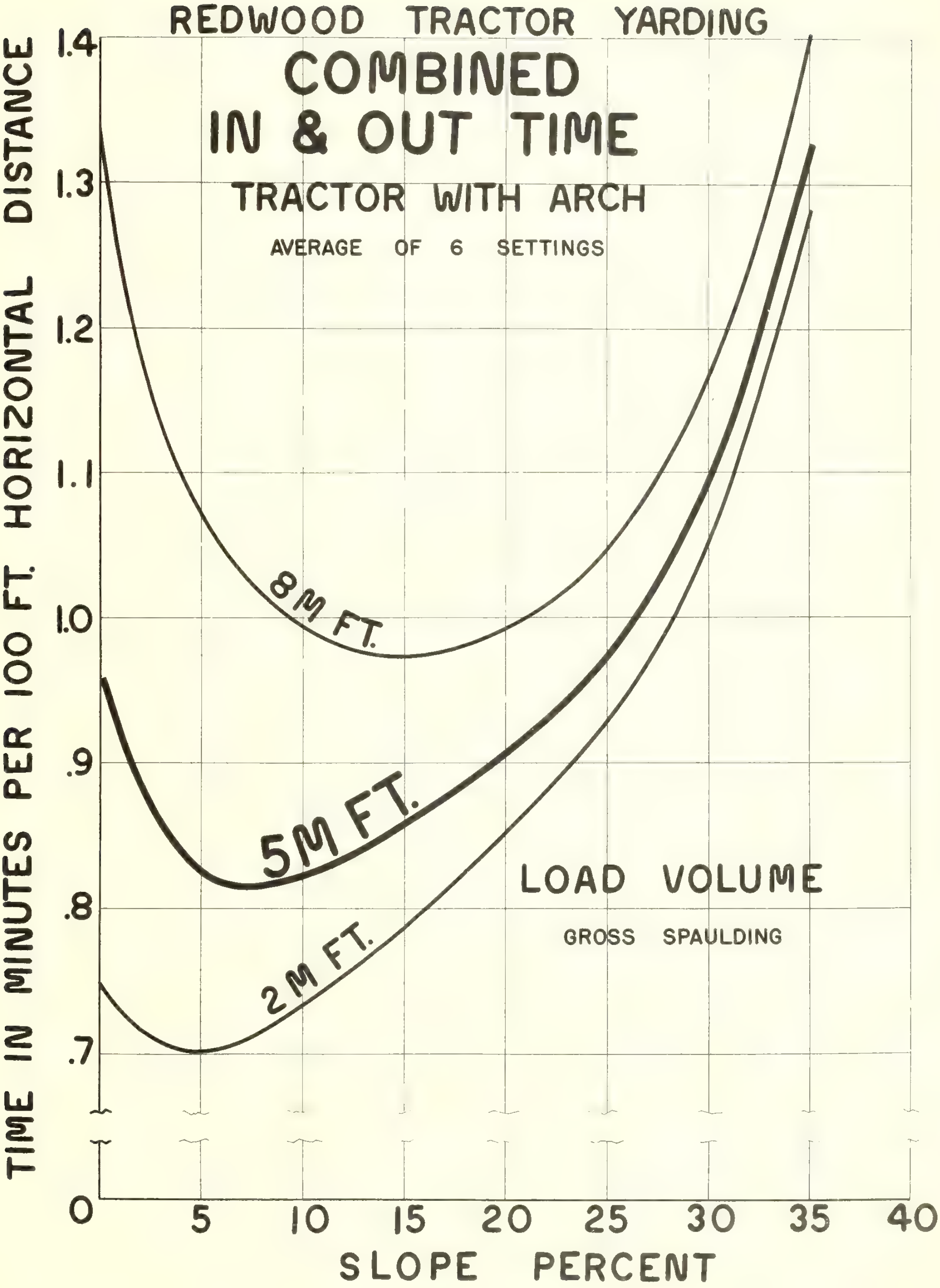
REDWOOD TRACTOR YARDING
COMBINED
IN & OUT TIME
TRACTOR WITH ARCH
AVERAGE OF 6 SETTINGS
8M FT.
5M FT.
2M FT.
LOAD VOLUME
GROSS SPAULDING
TIME IN MINUTES PER 100 FT. HORIZONTAL DISTANCE
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
0
5
10
15
20
25
30
35
40
SLOPE PERCENT

Figure 1

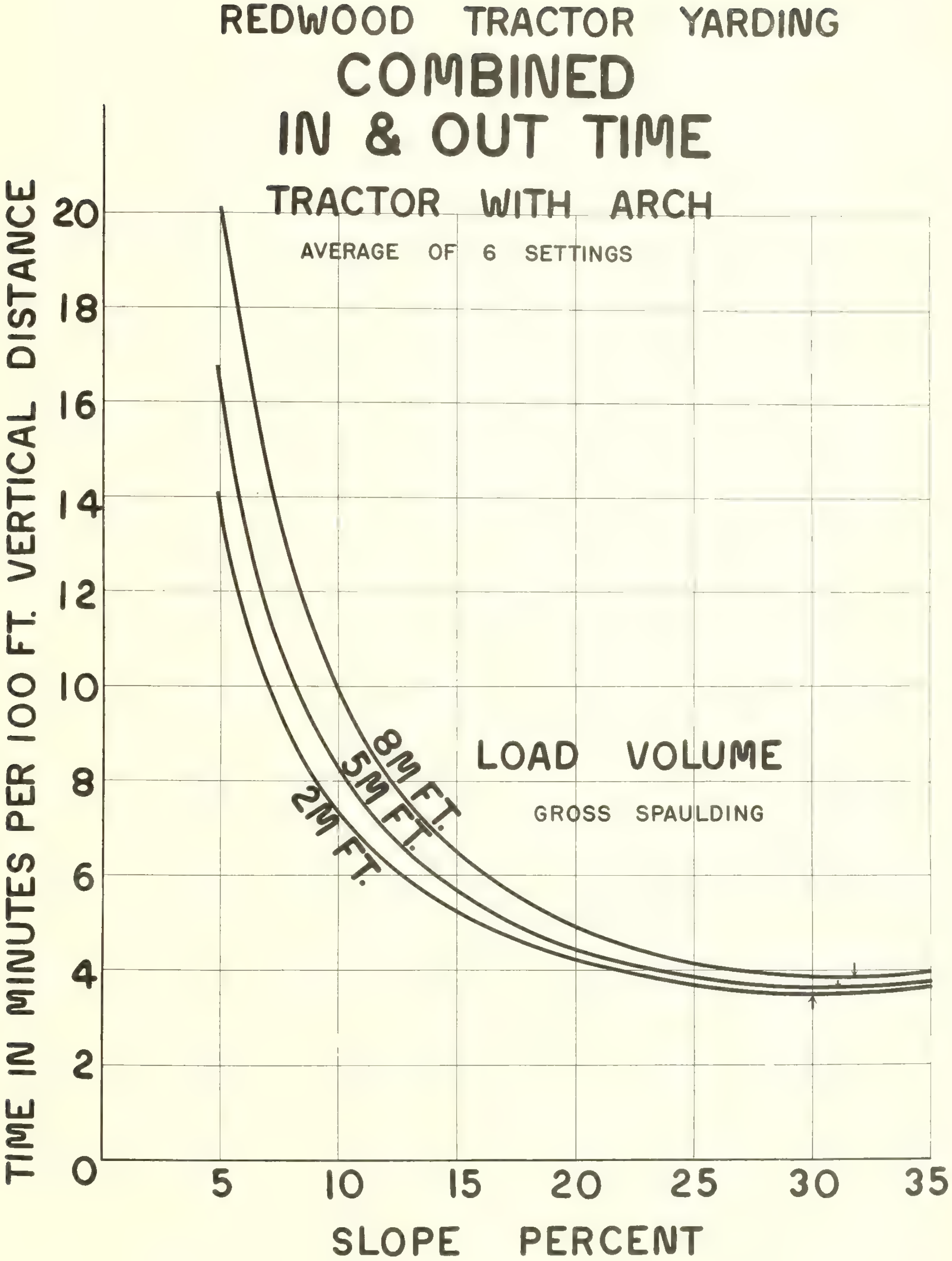
REDWOOD TRACTOR YARDING
COMBINED
IN & OUT TIME
TRACTOR WITH ARCH
AVERAGE OF 6 SETTINGS
LOAD VOLUME
GROSS SPAULDING
8M FT.
5M FT.
2M FT.
TIME IN MINUTES PER 100 FT. VERTICAL DISTANCE
0
2
4
6
8
10
12
14
16
18
20
5
10
15
20
25
30
35
SLOPE PERCENT

Figure 2

Although slope gradient is very important in tractor road location other things must be considered also, such as cost of construction, location and amount of timber, and the need for avoiding sharp curves which cause the logs to bind on the bank or stumps.

Size of Load

Because the total round trip time for large loads is not much greater than it is for small loads, the round trip time per M.B.M. is much smaller for large loads.[2] The round trip time per M.B.M. for 1,000 foot loads (gross scale) is approximately four times that for 5,000 foot loads (see figure 3). Loads from 5,000 to 8,000 feet (gross scale) are the most efficient. The data for loads over 8,000 feet are not adequate as the basis for definite conclusions, but this weakness is not serious because the capacity of the arch does not permit many loads over 8,000 feet.

The following data taken from figure 3 illustrate the value of large loads. Assuming all loads to be 4,000 feet or 6,000 feet the output would increase 27 percent in changing from 4,000 feet to 6,000 feet, or in a more extreme case the output would increase 91 percent in changing from 3,000 foot loads to 7,000 foot loads. Size of load can be increased by taking in more logs per load or by bucking longer logs. Both methods should be used.

The ideal condition would be single-log loads of 5000 feet and over. Some of the advantages of single-log loads are: less time for setting chokers, hooking and unhooking, assembling or bunching loads, and lifting load and adjusting it in the arch. Obviously, all logs cannot be 5000 feet or more in volume; but by cutting more long logs the average volume per log can be markedly increased. On the selectively cut Henry Creek area 56 percent of a total of 791 logs scaled were 52 inches or more in diameter and 90 percent were 37 inches or more. A 52-inch log 40 feet long scales 5061 feet (gross Spaulding) and a 37-inch log 40 feet long scales 2531 feet. In this case by cutting large logs not over 40 feet in length approximately half of them could be taken in single log loads 5000 feet or over in volume and nearly all in either one or two-log loads 5000 feet or over in volume.[3]

In smaller timber, such as is commonly found in Mendocino County, much of the timber could be logged in tree lengths and bucked at the landing. In addition to having greater volume per log, by use of tree lengths and coordination of falling with road location, the amount of spur roads or travel off the roads could be reduced.

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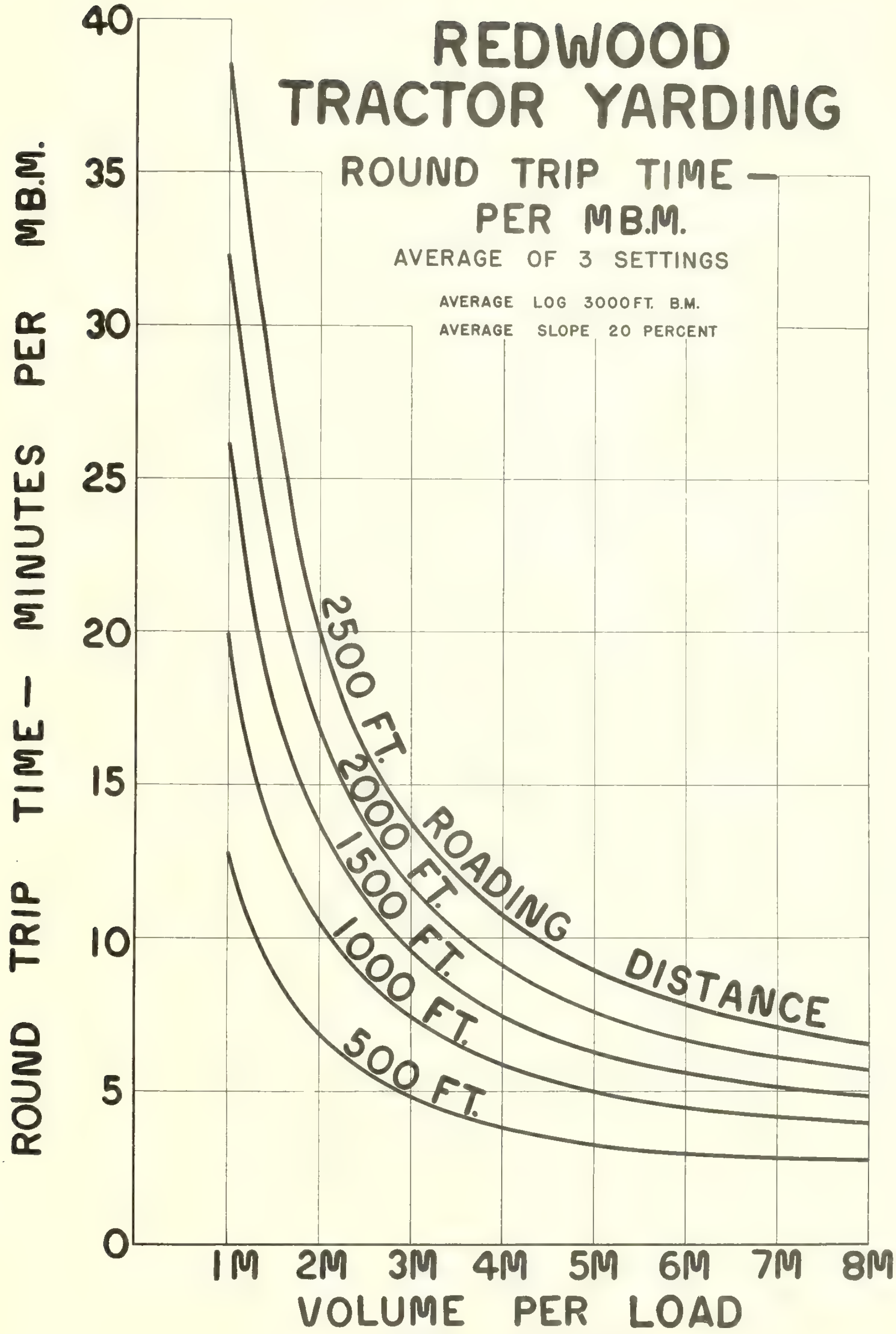
[2] For further discussion see Importance of large loads in redwood tractor logging. R. Stahelin and [illegible]. Bellin. West Coast Lumberman. February 1937.

[3] On this operation the lack of a bucking saw at the mill prevented the use of long logs.



GROSS SPAULDING

Figure 3

Uniform Production

For most efficient results a uniform flow of logs into the landing is desirable. Roading delays due to waiting for logs to be bunched by a skid cat or double drum, or waiting for peelers to finish peeling the logs, should be eliminated. Delays due to waiting for logs to be bunched can be largely eliminated by using long logs and by bunching logs, when necessary, in small groups some time ahead of the roading. Any extra peeling necessary in addition to that done by the regular peelers should be done at the landing. On all settings studied where this extra peeling was done in the woods considerable lost time resulted from waiting for peelers. In some cases this increased the total time as much as 18 percent. In order to insure uniformity of production of logs, close supervision is necessary to see that long hauls are balanced with short hauls rather than to clean out an area in one sweep from the landing to the back end of the setting.

In conclusion, data presented show some of the effects upon tractor yarding efficiency of slope gradients and size of loads. Much, however, remains to be known. Realization of maximum efficiency in the redwoods will come only with further experience in tractor operation, adequate cost records, mechanical studies, and additional time studies.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 23

October 11, 1939
Revised May 1951

CHEMICAL KILLING OF SPROUTING STUMPS

By H. D. Bruce, Chemist

After land has been cleared of shrub or tree growth by fire or cutting, species that have the capacity to sprout from the stump or base of the stem soon send up vigorous, dense, brushy growth which is objectionable from such standpoints as fire protection and improvement maintenance. Included among such sprouters in California are all the tree and scrub oaks, certain manzanita and ceanothus species, and such other native shrubs as chamise, Christmas berry, California coffee berry, sugar sumac, Sierra chinquapin, and birchleaf mountain-mahogany. Of those, highland live oak, including the tree (Quercus wislizenii) as well as the shrub form (var. frutescens), is one of the most vigorous and persistent sprouters and one of the most troublesome. This species is of common occurrence over wide areas in the foothills and mountains of California.

Several introduced trees such as eucalyptus and acacia are also vigorous sprouters and frequently present difficult control problems in both rural and urban areas.

In figure 1 is shown a typical live oak a few years after cutting. Such a bush may not only usurp valuable forage land but is always a potential fire hazard because of its inflammability and fire-spreading characteristics. It cannot be killed by chopping off the branches or by burning, for after such treatment the stump sends forth new growth from the base and becomes more voluminous and more objectionable than ever.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Agriculture--Berkeley

The eradication of sprouting brush is a difficult problem, and considerable study has been undertaken to find a cheaper, quicker, and more positive method than blasting or grubbing. One solution of the problem has been found in poisoning with herbicidal chemicals as hereinafter described.

Of several chemicals tested extensively as a stump poison, ammonium sulfamate has proved both effective and reliable. It is a white, crystalline, water-soluble salt, which can be purchased from chemical supply houses for 18 to 20 cents per pound. It is available in small quantities at local hardware and garden supply retailers under the trade-name "Ammate." It is used as a solution (approximately 15 percent) prepared by dissolving $1\frac{1}{2}$ pounds of the salt in 1 gallon of water.

In poisoning a stump with ammonium sulfamate there are four operations, as follows:

1. Desprouting (fig. 2). All sprouts are chopped off at the crown with an axe. The purpose of desprouting is to gain access to the stump and to facilitate later operations.

2. Unearthing (fig. 3). The soil or duff immediately around the stump is removed with a shovel or mattock to a depth of 3 or 4 inches, exposing all budding tissue and any large radial roots. At the same time loose litter is removed from the top of the crown so that all live portions of the stump are clearly defined.

3. Hacking (fig. 4). All live tissue is then scarred by lightly hacking through the bark. The chips are allowed to remain in place to catch and retain the poison. It is particularly important to make a complete girdle of cuts at and below ground level where new sprouts are apt to develop. Hacking is the most important operation and should be thorough.

4. Spraying (fig. 5). The 15-percent solution of ammonium sulfamate is applied to the fresh cuts. This is done most easily by manipulating a stream of the liquid from the nozzle of a portable sprayer. Only enough solution need be applied to saturate the freshly cut surfaces.

In figure 6 is shown the dead stump after chemical treatment of the sprouting stump pictured in figure 1.

A complete kill of about 95 percent of stumps treated in this way can be expected from a single application of ammonium sulfamate. In the surviving stumps an occasional sprout will later develop but will easily succumb to a second treatment. The success from the first application falls off sharply when the stumps exceed 25 inches in diameter because the larger stumps are more irregular and more difficult to prepare. Added care in step 3, above, will result in equal success.

Six to ten stumps of average size can usually be treated with one gallon of solution. The average workman can treat from four to eight stumps an hour. There is little or no seasonal difference in the resistance or susceptibility of the plants to ammate. There also seems to be little difference in susceptibility to ammate among the common sprouting species, although there is a difference in the ease with which the stumps can be girdled.

In contrast with chemicals formerly used, ammonium sulfamate is not toxic to animals nor is it inflammable. Ammate is somewhat corrosive to metal, however, and containers and applicators should therefore be rinsed thoroughly after ammate has been used in them.

Chemical killing of sprouting stumps has been used extensively and successfully in the construction and maintenance of firebreaks and roadsides in the forests of California. The method should be of economic utility for maintaining clearings around forest-guard stations, lookout towers, public campgrounds and smoking areas, under electric power lines, and along railroad rights-of-way. Ammonium sulfamate can be used to remove willows and alders from the banks of reservoirs, irrigation ditches, and flood-control channels. Householders find the method both cheap and positive for ridding their property of unwanted eucalyptus, redwood, and other sprouting species. For large-scale clearing of undesirable trees on range land the method is not cheap, but the application of chemical at the time of the original clearing, when trees are felled for wood, is convenient and insures valuable forage land against later encroachment of brush issuing from the old stumps. The advantage of eradicating stumps with chemicals has been repeatedly proved in forestry practice and with adequate attention to the requirements for careful application the method is both certain and economically practical.

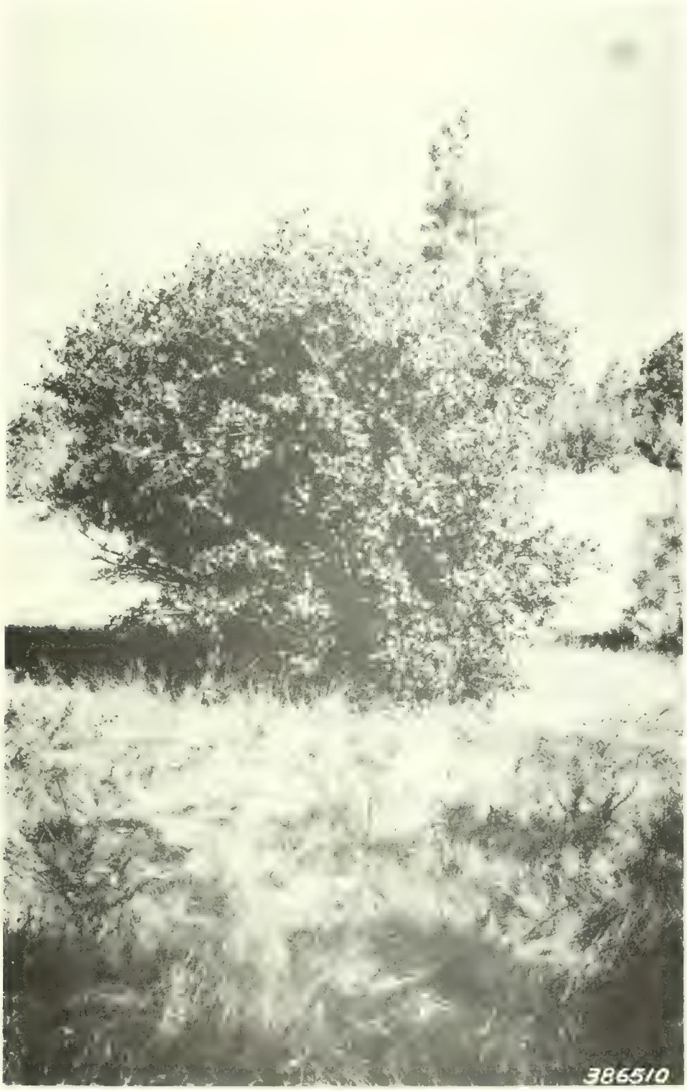


Figure 1. A sprouting live oak stump.

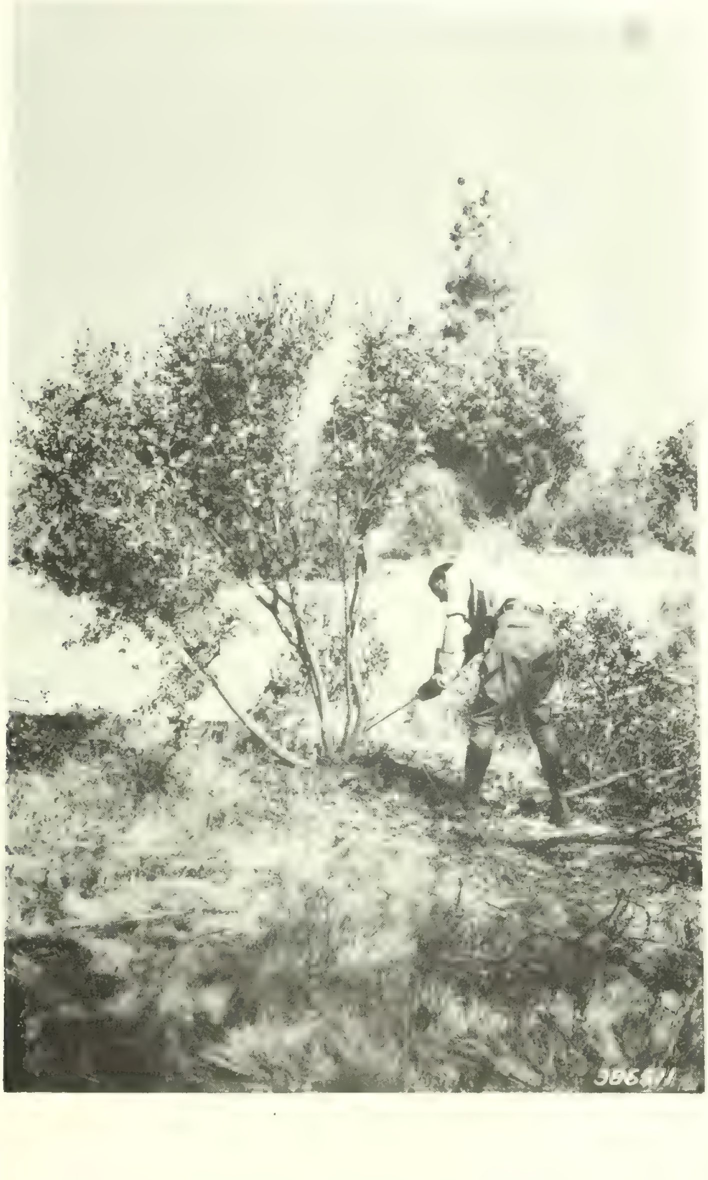


Figure 2. First operation: desprouting.

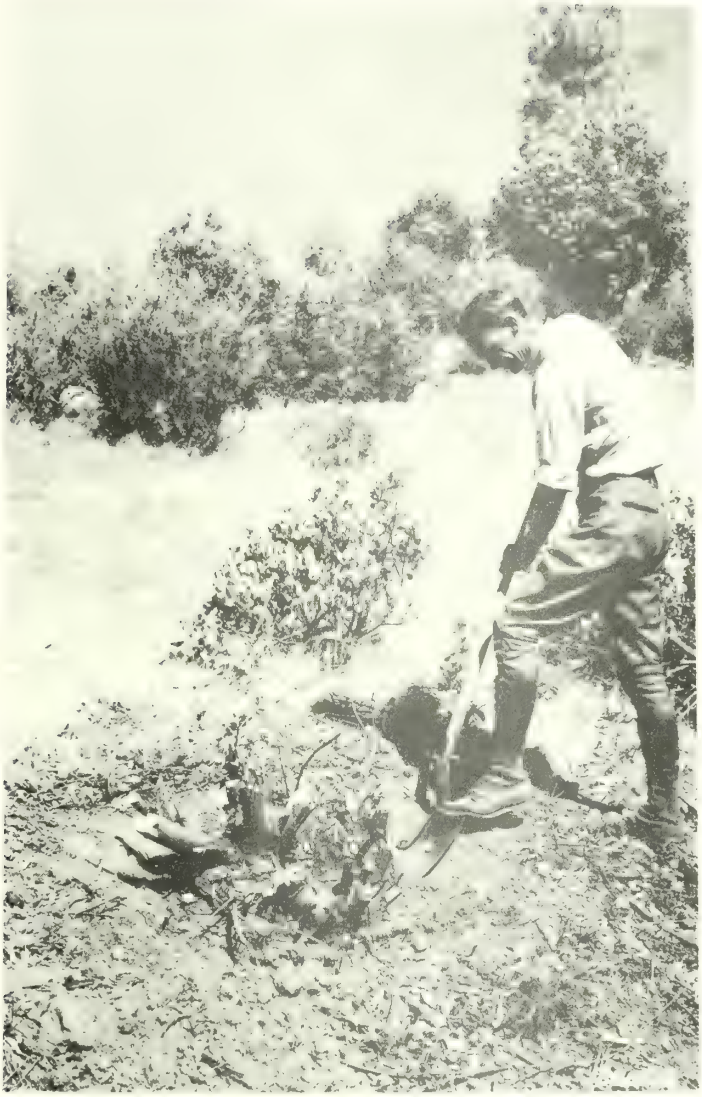


Figure 3. Second operation: unearthing.

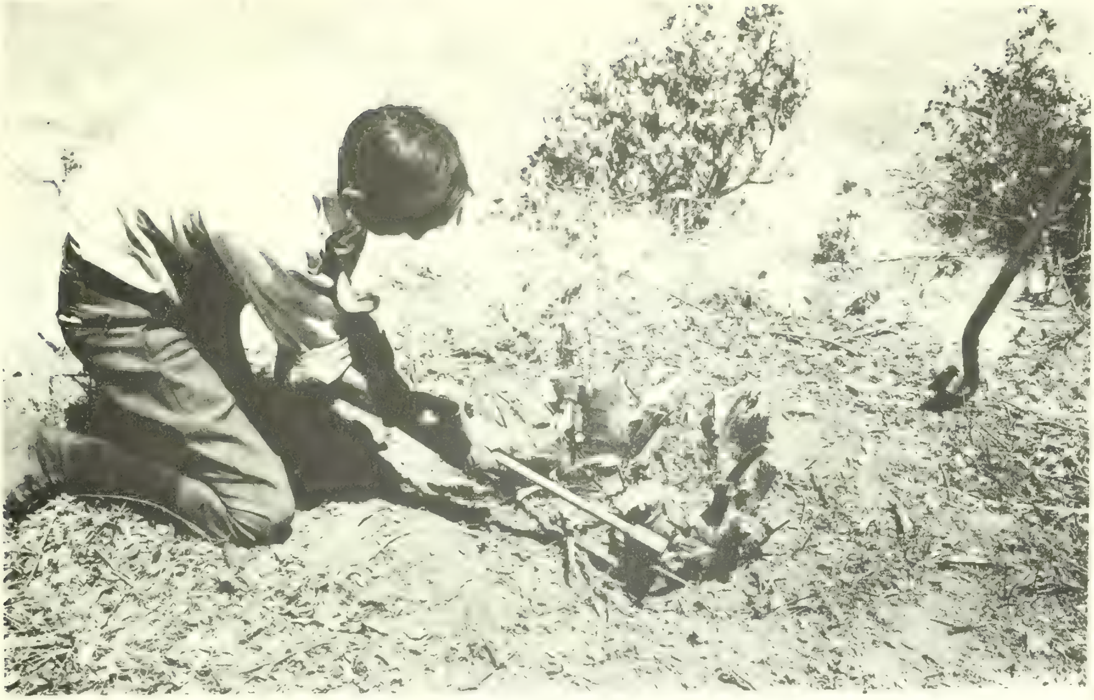


Figure 4. Third operation: hacking.

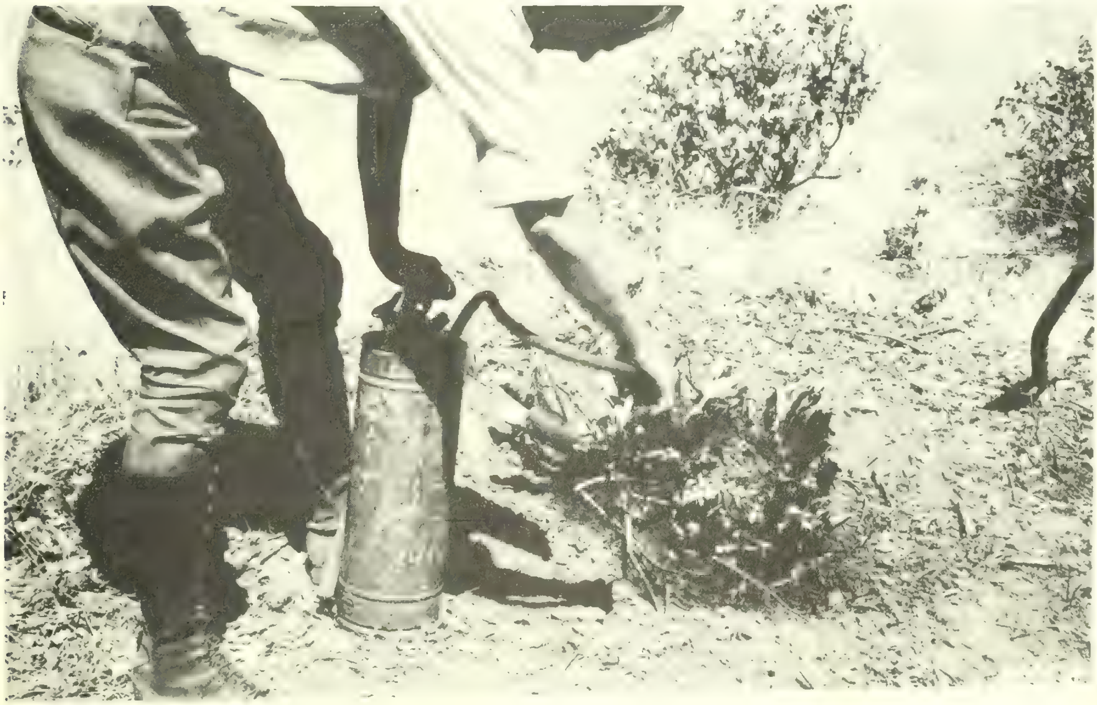


Figure 5. Fourth operation: spraying the fresh cuts.

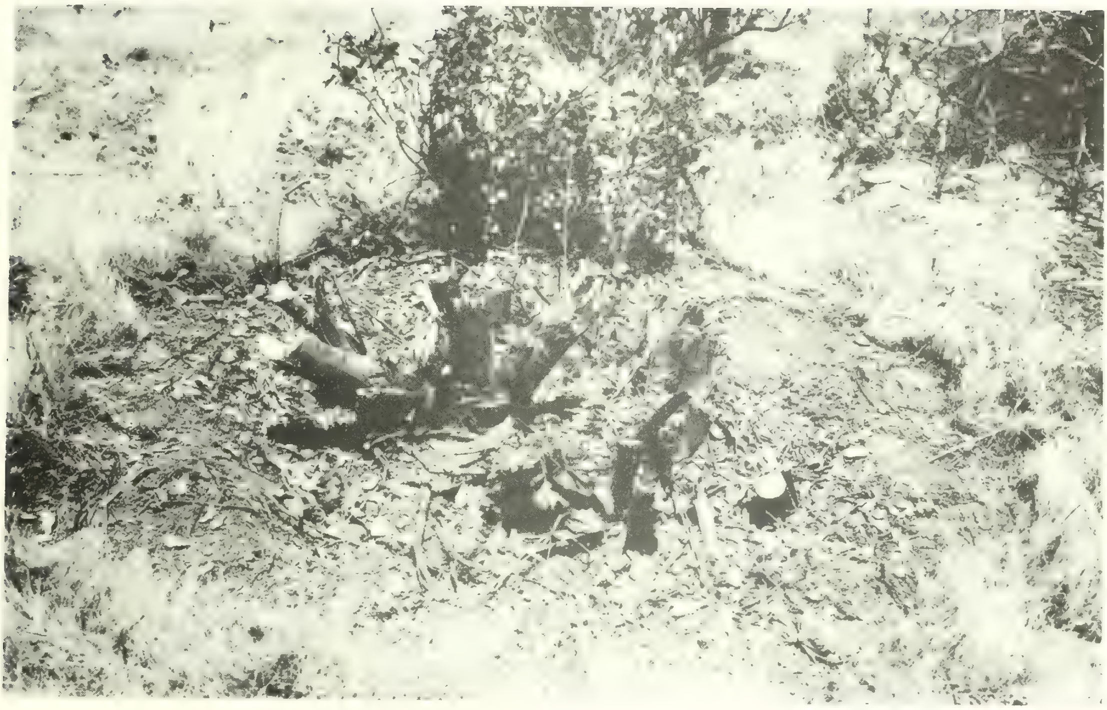


Figure 6. The treated stump a year later, completely killed by the single application.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

Research Note No. 26 February 28, 1942

A KEY FOR IDENTIFYING SOME IMPORTANT ANNUAL RANGE GRASSES IN THE IMMATURE STAGE

By

A. L. Hormay [1]
Associate Forest Ecologist

A simple key for identifying annual grasses in their early stages of growth has been needed in the past few years by several agencies, including the Forest Service, the Soil Conservation Service, and the Agricultural Adjustment Administration, which have been conducting various surveys on annual-type ranges in California. Frequently it was necessary to begin these surveys in late winter before the vegetation had reached the flowering stage, and the species had to be distinguished on the basis of their vegetative characteristics. Identification of species, therefore, was not always possible. Grasses gave special difficulty because of the similarity of the species.

There are approximately 118 species of annual grasses in California, but only about 10 may be considered to have range importance from the standpoint of abundance and forage value. These 10 were included in a key and descriptions of 20 annual grasses prepared by the author 10 years ago to facilitate some range investigations. In order to meet the present field needs of the several agencies actively engaged in carrying out surveys in the annual types of California, the key and descriptions have been revised in less technical form and are presented in the following pages.

1/ The author is grateful to Mrs. Dorothy K. Dick of this Station for many valuable suggestions that have made this work more practical and usable, and to Miss Beryl O. Schreiber for technical comments that improved the taxonomic presentation.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

In using the key and the descriptions, it is well to bear in mind that these annual grasses continually change in outward appearance from the earliest stages of growth until maturity. The size and shape of the various plant parts, the number of veins, the relative hairiness, and even the character of the hairs are different in each newly developing part. These characteristics are related to the stage of growth of the plants.

Environment or habitat also influences the outward expression of the plant. Plants growing in dense stands are usually taller, more spindly, more succulent, and often less hairy than those growing in more open stands. Many of the forms growing in the open tiller extensively and present a more robust and spreading habit.

Most of the species included in the present key were checked in the field in several localities, and a wide range in size, shape, and hairiness was observed in the same species. These variations, coupled with those due to growth, and the fact that the characters observed on the plants were limited to those that could be seen with the naked eye or with a hand magnifier of 10 power or less, prevented the differentiation of certain species and left room for improvement in the classification of some others. Additional information on the variability of these annual grasses can be used to improve the present work. It should serve a useful purpose in its present form, however, since there is a lack of vegetative descriptions of the annual grasses in California.

It cannot be stressed too strongly that use should be made of all the information presented in the key and in the descriptions in judging each species. Consideration should be given to the conditions under which the plant is found growing, since these may affect the relative weight which may be ascribed to plant characters such as size, stature, and relative hairiness. The approximate width and number of veins in successively appearing leaf blades have been included in table form in many of the species descriptions to serve as an aid in identification, although the variation in this type of data makes the values relative rather than absolute. The shape of the ligules has been illustrated because of their importance in identification. The characteristics of the seed have also been included in the species descriptions. The seed from which the grass seedling germinated may be found attached to the base of some plants. To aid in identification care should be taken to collect it or any portion of it that remains.

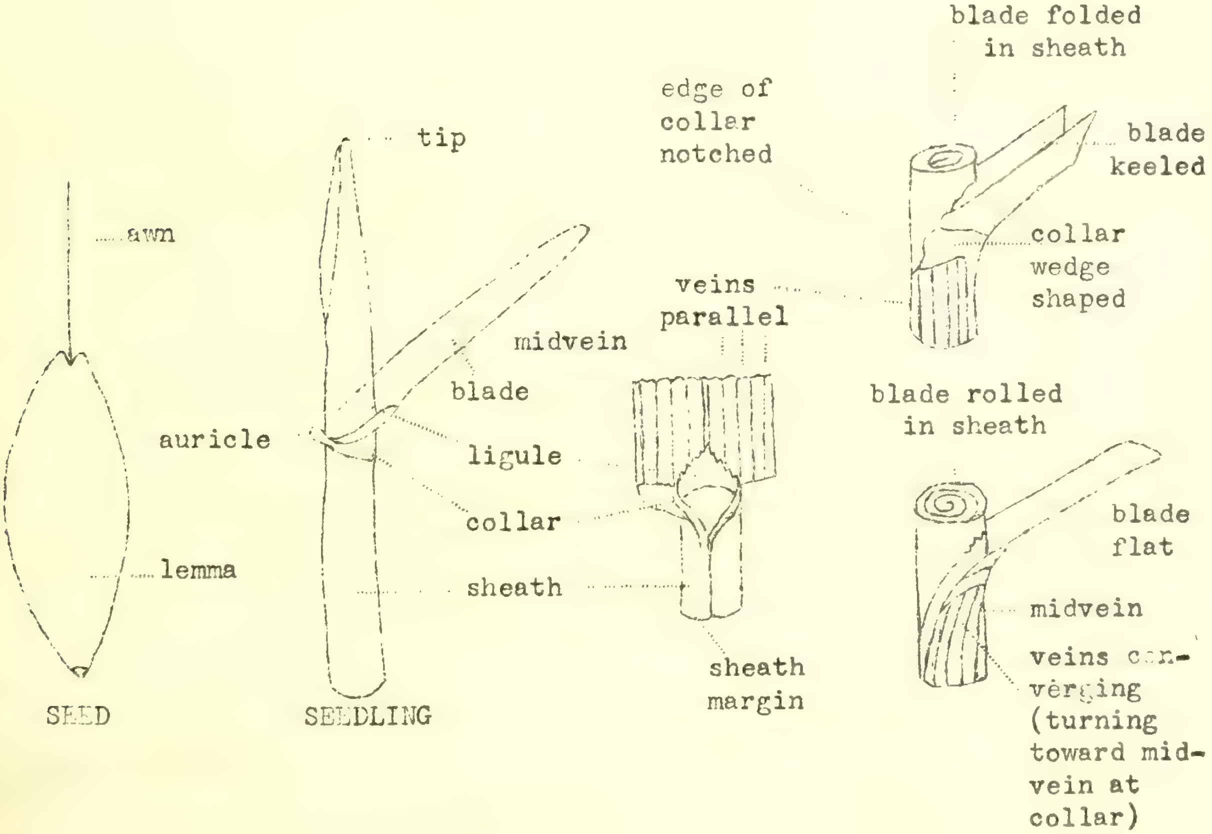
The present descriptions were made from living plants and therefore are applied best to living plants. The hairs, the color and shininess of the plant, and other characteristics are changed considerably in some dry specimens. The descriptions apply to plants in which four to eight leaves have been completely developed. Younger or older plants may not show all the characters that are given in the descriptions or may exhibit different ones.

The use of some technical terms is unavoidable in referring to the parts of a grass seedling. A reader not familiar with the morphology of grasses should refer to a suitable text for more detailed drawings and descriptions than are given here. Some of the essential terms and parts of the grasses referred to in this paper are defined or illustrated below. A 6- to 10-power magnifying lens is essential for seeing many of the finer characteristics of the plants.

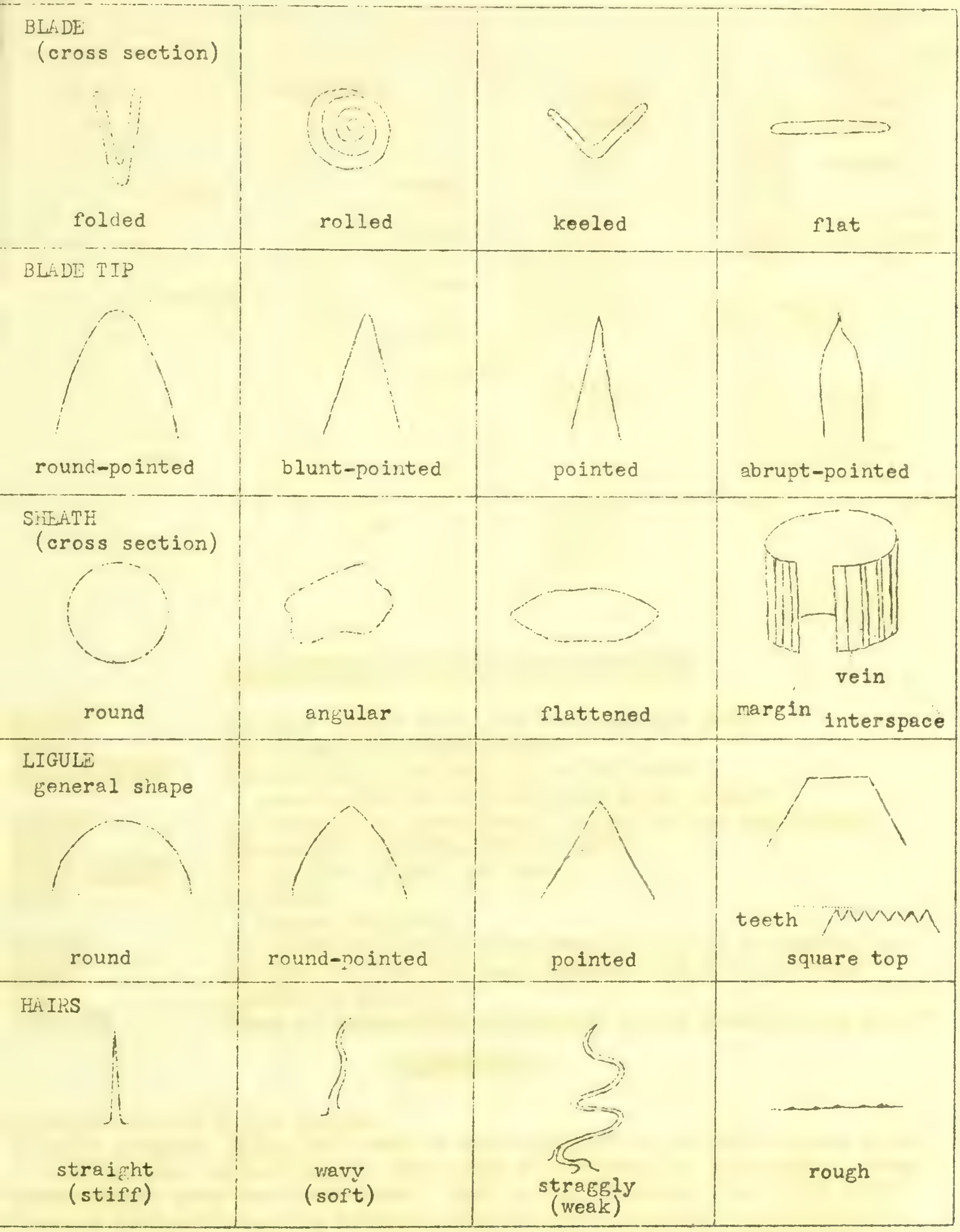
Definitions

Auricles	Lobes or claw-shaped appendages on the edges of the collar.
Awn	A beard or bristle.
Blade	The part of the leaf that extends away from the stem.
Collar	The distinct line or zone where the blade and sheath are joined together.
Culm	The stem.
Inner surface	The surface facing the stem.
Lemma	The chaffy bract around the grain.
Ligule	The portion of inner papery lining of the sheath that extends upward past the base of the blade.
Outer surface	The surface facing away from the stem.
Seed	The lemma and enclosed grain.
Sheath	The part of the leaf that envelops the stem.

Illustrations of Plant Parts and Terms



OUTLINES


BLADE
(cross section)
folded
rolled
keeled
flat
BLADE TIP
round-pointed
blunt-pointed
pointed
abrupt-pointed
SHEATH
(cross section)
round
angular
flattened
vein
margin
interspace
LIGULE
general shape
round
round-pointed
pointed
teeth
square top
HAIRS
straight
(stiff)
wavy
(soft)
straggly
(weak)
rough

A KEY FOR IDENTIFYING SOME IMPORTANT ANNUAL RANGE GRASSES IN THE IMMATURE STAGE

(Applicable to live plants with four to eight leaves. Characters observable with a 6- to 10-power magnifying lens; some are visible to the naked eye.)

A. Auricles present, claw-shaped, 0.5 - 1 mm. long...1. Mouse barley

B. Auricles absent, or, if present, only lobed, not claw-shaped.
    1. Plants obviously hairy, hairs sometimes few and localized, but readily seen.
        a. Sheaths hairier than blades; hairs on sheaths and blades not same kind.
            1. Sheaths with long wavy, weak straggly hairs; hairs on blade straighter, shorter; ligules 1 mm. long, with straggly hairs on outer surface. 2. Soft chess
            .... 3. Smooth chess
            2. Sheaths with long, slender, straight or wavy hairs; blades only sparingly hairy; ligules 1 - 4 mm. long, with no hairs on outer surface. ......4. Chilian chess
        b. Sheaths not hairier than blades; hairs on sheaths and blades same kind.
            1. Blades covered with fine hairs on both surfaces.
                (a) Hairs more than 0.5 mm. long; plants evenly or unevenly hairy, not grayish from hairs, not velvety.
                    (1) Ligules hairy on outer surface ....5. Australian chess
                    (2) Ligules not hairy on outer surface.
                        a'. Margin of ligules fringed with slender, tapering teeth, the tips bent and wavy; plants have silky hairs. ....6. Downy chess
                        b'. Margin of ligules saw-toothed; the teeth broad and triangular, the tips stiff and straight; plants have stiff hairs.
                            1'. Notches between teeth of ligules somewhat rounded; some teeth tapering. ....7. Ripgut grass
                            2'. Notches between teeth of ligules pointed; the teeth broad and triangular. ....8. Poverty brome
                (b) Hairs very short, less than 0.5 mm. long; plants evenly hairy, grayish, velvety.
                    (1) Ligules 0.5 - 1 mm. long, square on top, not hairy on outer surface. 9. Mediterranean barley

(2) Ligules 1 - 3 mm. long, blunt-pointed, sparsely hairy on outer surface. ....10. Red brome

2. Blades with sparse coarse hairs only on edges or mid-vein near base. ....11. Wild oat

2. Plants not obviously hairy; sometimes rough to the touch.

a. Plants light to dark green; blades broad, 2 - 11 mm. wide, 3 - 29 veined, rolled in sheath (folded in annual bluegrass), always much wider than diameter of sheath.

1. Collars at angle of 45° to 60° with long axis of stem; plants small, 1 - 5 inches high; blades usually not more than 1 - 4 inches long.

(a) Ligules pointed, tip sometimes slightly notched; blades rolled in sheath; plants silvery gray-green. ....12. Little quaking grass

(b) Ligules rounded, sometimes tipped with a small tooth; blades folded in sheath; plants dark green. ....13. Annual bluegrass

2. Collars at right angles with long axis of stem; plants large, 2 - 10 inches high; blades 2 - 10 inches long.

(a) Ligules 0.5 - 0.8 mm. long, smooth on outer surface. ....14. Spanish brome

(b) Ligules 1 - 5 mm. long, rough on outer surface.

(1) Ligules showing strong green vertical veins; rounded in outline and cut into several long teeth. ....15. Nitgrass

(2) Ligules not showing green vertical veins; round-pointed or squared on top, with fine short teeth.

a'. Ligules round-pointed; teeth small, widely spaced, the spaces between teeth shallow dished. ....11. Wild oat

b'. Ligules round to square on top, sharply toothed, notches between teeth pointed. ....16. Slender oat

b. Plants generally dark shiny green; blades slender, 0.5 - 2.5 mm. wide, 3 - 9 veined, folded in sheath, little if at all wider than diameter of sheath.

1. Ligules 0.3 - 0.5 mm. long, inconspicuous, square on top.

(a) Collar thickened, edges apparently extending upward about 1 mm. on edges of blade; blades form an angle of 45° or more with stem. ....17. Pacific fescue

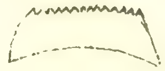
(b) Collar not thickened, edges not extending upward onto blade; blades form an angle of less than 45° with stem. ....18. Foxtail fescue

..................................19. Rat-tail fescue

2. Ligules 0.5 - 3 mm. long, conspicuous, pointed. 20. Silver hairgrass

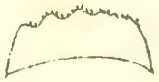
Descriptions of Species, Including Illustrations of Ligules

1. Mouse barley   Hordeum murinum L.
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 5 - 6 mm. wide, 14 - 21 veined, with soft hairs on both surfaces, sometimes nearly smooth near base and on edges; tips round-pointed; sheaths round, soft hairy; ligules square and finely toothed on top, 1 - 1.5 mm. long, not hairy; collars wedge-shaped, not hairy; auricles claw-shaped, 0.5 - 1 mm. long, developing on about the fourth leaf; lemma 10 - 14 mm. long, rough; awn about 2 - 3 cm. long, attached to lemma at tip.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	7	10	12	14	15	17	19	21
Approx. width mm.	2	3	4	5	6	6	6	6

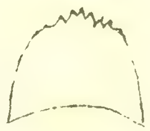
2. Soft chess   Bromus mollis L. (B. hordeaceus) (L.)
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 3 - 5 mm. wide, 11 - 15 veined, with soft, straight hairs about 0.5 mm. long on both surfaces, sometimes smooth for 3 - 5 mm. above ligule; tips blunt-pointed; sheaths round, with covering of wavy and straggly hairs 1 - 1.5 mm. long; ligules rounded, 1 mm. long, with straggly hairs on outer surface, coarsely toothed, the margins of teeth finely notched; collars wedge-shaped, not hairy, lemma 8 - 10 mm. long, hairy; awn 6 - 9 mm. long, attached about 1 mm. below tip of lemma.



Leaf no.	1	2	3	4	5	6	7
Approx. no. of veins	3	5	9	11	12	12	13
Approx. width mm.	1	1.5	2	3	3.5	4	5

3. Smooth chess   Bromus racemosus L.
Has characteristics of soft chess, except lemma smooth or rough, not hairy.

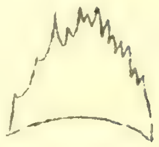
4. Chilian chess   Bromus trinii Desv.
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 3 - 9 mm. wide, 7 - 18 veined, sparsely hairy near edges on upper surface, under surface not hairy; tips blunt-pointed; sheaths round, with dense covering of long wavy hairs 1 - 1.5 mm. long; ligules round-pointed, not hairy, 1 - 4 mm. long, the top with small teeth; collars wedge-shaped, not hairy; lemma hairy, 10 - 12 mm. long, tipped with two bristles 2 - 3 mm. long; awn 1 - 1.5 cm. long, twisted, bent below middle, attached 2 or 3 mm. below tip of lemma.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	5	5	5	7	9	12	13	18
Approx. width mm.	1.2	2	2	3	3	5	7	9

5. Australian chess Bromus arenarius Labill

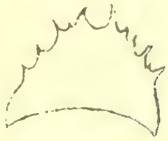
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 3 - 6 mm. wide, 11 - 19 veined; both surfaces and margins with soft hairs of unequal length, tips pointed; sheaths round, with hairs like those on blades, but somewhat longer; collars indistinct, wedge-shaped; ligules round-pointed; sparsely hairy on outer surface, 1 - 2.5 mm. long, with fine, sharp, irregular teeth, vertical veins not evident; lemma 10 - 12 mm. long with dense short hairs; awn straight, 10 - 16 mm. long, attached to lemma about 2 mm. below tip.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	5	9	11	11	15	17	17	19
Approx. width mm.	1.5-2	2	3	3	4	5	5	6

6. Downy chess Bromus tectorum L.

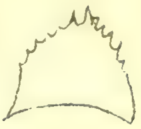
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 3 - 4 mm. wide, 10 - 14 veined, with soft hairs on both surfaces, upper surface hairy to very base, tips round-pointed; sheaths round, covered evenly with soft hairs; ligules round, 1 - 1.5 mm. long, not hairy or with a few short hairs, margins fringed with slender tapering teeth, the tips bent and wavy; collars wedge-shaped, densely hairy; lemma hairy or smooth, 10 - 12 mm. long; awn 12 - 14 mm. long, attached to lemma 2 - 3 mm. below tip.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	5	7	9	10	11	12	13	14
Approx. width mm.	1	2	3	3	4	4	4	4

7. Ripgut grass Bromus rigidus Roth

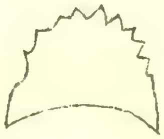
Plants hairy, gray green; blades rolled in sheaths, flat when grown out, 3 - 6 mm. wide, 9 - 13 veined, both surfaces with fine straight, stiff hairs, sometimes upper surface smooth just above collar and ligule, tips round-pointed; sheaths round, in some plants with hairs like those on blades, in others almost smooth, veins prominent, widely spaced, converging and turning noticeably toward midvein near collar; ligules round, not hairy, 1 - 2 mm. long, with small sharp teeth, the notches between the teeth rounded; collars wedge-shaped, smooth or with stiff hairs; lemma 2.5 - 3 cm. long, rough; awn 4 - 6.5 cm. long, attached to back of lemma about 5 - 7 mm. below tip.



Leaf no.	1	2	3	4	5	6	7
Approx. no. of veins	7	9	11	11	12	13	13
Approx. width mm.	2.5	3	4	5	5	6	6

8. Poverty brome *Bromus sterilis* L.

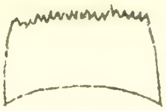
Plants hairy, light green; blades rolled in sheaths, flat when grown out, 4 - 6 mm. wide, 11 - 15 veined, with soft hairs, tips round to blunt-pointed; sheaths with hairs like those on blades, sometimes only midvein hairy; ligules round, not hairy, 1 - 1.8 mm. long, with sharp triangular teeth, the notches between the teeth pointed; collars wedge-shaped, smooth on under surface, with minute hairs on upper surface above ligule; lemma rough, 1.7 - 2.0 cm. long; awn 2 - 3 cm. long, attached to lemma 1 - 2 mm. below tip.



Leaf no.	1	2	3	4	5	6	7
Approx. no. of veins	5	9	10	11	12	13	15
Approx. width mm.	1.5-2.5	3	3	4	5	5	6

9. Mediterranean barley *Hordeum gussoneanum* Parl.

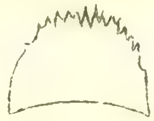
Plants hairy, gray green; blades rolled in sheaths and flat when grown out, 2 - 3 mm. wide, 9 - 13 veined, with dense even growth of short hairs on both surfaces and edges to very base, velvety, tips blunt-pointed; sheaths round, with dense uneven growth of short hairs; ligules 0.5 - 1 mm. long, not hairy, square with small sharp teeth on top; collars wedge-shaped, smooth or with minute hairs; lemma smooth, 5 mm. long; awn 6 - 10 mm. long, attached to lemma at tip.



Leaf no.	1	2	3	4	5	6	7
Approx. no. of veins	5	5	7	9	10	11	13
Approx. width mm.	1.5	1.5	1.8	2	2.8	3	3

10. Red brome *Bromus rubens* L.

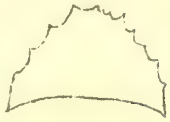
Plants hairy, gray green; blades rolled in sheaths, flat when grown out, 3 - 4 mm. wide, 9 - 13 veined; blades with dense, even growth of short hairs on both surfaces and edges to very base, velvety, tips abrupt-pointed; sheaths round, hairs like on blades; ligules sparsely hairy on outer surface, round-pointed, 1 - 3 mm. long, with small sharp teeth; collars wedge-shaped, not hairy; lemma rough or hairy, 12 - 16 mm. long; awn 16 - 20 mm. long.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	3-5	5	7	9	10	11	11	13
Approx. width mm.	1.5	2	2	3	3	3	3.5	3.5

11. Wild oat Avena fatua L.

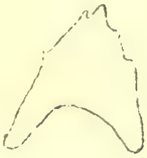
Has characteristics of slender oat, but plants more robust and usually set with few to many long, straight, stiff hairs on margins and midvein of blades near base and on collars and upper portion of sheaths, some plants not hairy or with hairs only on margins of upper part of sheaths; ligules round-pointed, with small widely spaced teeth, the spaces shallow dished, vertical veination evident; lemma 14 - 18 mm. long, with conspicuous, long, stiff hairs; awn 3 - 4 cm. long, bent and twisted below middle, attached near middle of back of lemma.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	7-11	11	13	15	13	15	17	20
Approx. width mm.	2-3	3	4	4	5	5	6	7

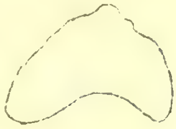
12. Little quaking grass Briza minor L.

Plants not hairy, dull, silver green; blades rolled in sheaths, flat when grown out, 2 - 5 mm. wide, 5 - 15 veined, broad at base and sharply tapering to tip, margins near base turned back, tips pointed; sheaths short, 3 - 20 mm. long, the latter barely surpassing the preceding, the blades thus crowded; ligules pointed, 1 - 2 mm. long, edges slightly undulating with occasional small round teeth, sometimes notched at tip, not hairy, not vertically veined; collars at angle of about 45° with main axis of stem, strongly keeled; lemma 1 - 1.5 mm. long and as broad, papery, smooth, awnless.



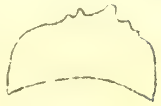
13. Annual bluegrass Poa annua L.

Plants not hairy, dark green; blades folded in sheaths, keeled near base and tip and almost flat in middle when grown out, 2 - 4 mm. wide, 3 - 11 veined, frequently transversely wrinkled, tips canoe-shaped; sheaths flattened, keeled; ligules round, 1 - 2 mm. long, not hairy, not vertically veined, frequently tipped with a small tooth, upper edges set with a few faint round teeth, the sides not toothed; collars at an angle of 45° - 60° with main axis of stem, edges notched; lemma about 2.5 mm. long, hairy on veins, awnless.



14. Spanish brome Bromus madritensis L.

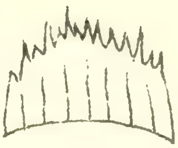
Plants not obviously hairy, gray green; blades rolled in sheaths, flat when grown out, 4 - 5 mm. wide, 11 - 15 veined, rough on both surfaces, tips blunt-pointed; sheaths round, rough or with minute hairs; ligules rounded, 0.2 - 0.8 mm. long with small rounded teeth on upper edges, not hairy; collars wedge-shaped, margins with short hairs; lemma smooth or hairy, 12 - 18 mm. long; awn 18 - 25 mm. long, attached to lemma about 3 mm. below tip.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	5	9	11	11	12	13	14	15
Approx. width mm.	1.7	2	3	4	4	5	5	5

15. Nitgrass Gastridium ventricosum (Gouan) Schinz. and Thell

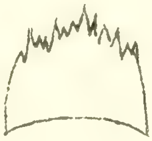
Plants not hairy, pale gray green; blades rolled in sheaths, tending to be keeled when grown out, 3 - 7 mm. wide, 11 - 21 veined, rough on both surfaces and edges, tips pointed; sheaths round, margins conspicuous, papery; ligules square on top, 2 - 4 mm. long, with vertical green veins, rough on outer surface; top cleft into several narrow tapering teeth; collars wedge-shaped; lemma globe-shaped, about 1 mm. long, hairy at top; awn 5 mm. long, bent near middle.



Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	3	5	7	11	13	15	19	21+
Approx. width mm.	0.5	1	2	3	4	5	6	7

16. Slender oat Avena barbata Brot.

Plants not hairy, light gray green; blades rolled in sheaths, flat when grown out, 3 - 5 mm. wide, 13 - 23 veined, marked with small white oblong specks on both surfaces, upper surface smooth or rough, under surface smooth and shiny, tips pointed; sheaths round; ligules round to square, 2 - 5 mm. long, rough on outer surface, finely toothed on top, vertical veins evident but not green; collars wedge-shaped; lemma 12 - 14 mm. long with conspicuous, long, stiff hairs; apex ending in two fine bristles 4 mm. long; awn 3 - 3.5 cm. long, bent and twisted below middle.



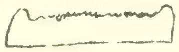
Leaf no.	1	2	3	4	5	6	7	8
Approx. no. of veins	5-9	12	13	13	15	17	19	23
Approx. width mm.	1.5-2	2	2	3	3	4	5	5

17. Pacific fescue Festuca pacifica Piper

Has characteristics of F. megalura except: collars thickened, edges extending upward about 1 mm. on margins of blades; blades extend at an angle of 45° or more from stem; lemma smooth or slightly rough, 4 - 5 mm. long; awn 8 - 12 mm. long, attached to tip of lemma.

18. Foxtail fescue Festuca megalura Nutt.

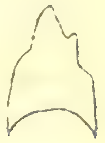
Plants not hairy, dark green; blades folded in sheaths, flat when grown out, 1 - 1.8 mm. wide, 5 - 9 veined, smooth, shiny on under surface, sometimes with fine hairs on upper surface, tips abrupt-pointed; sheaths angular; ligules square on top, 0.2 - 0.4 mm. long, not hairy, teeth small and widely spaced; collar a narrow band, margins often bulging; lemma rough on back, 5 - 6 mm. long; awn 8 - 15 mm. long, attached to lemma at tip.



19. Rat-tail fescue Festuca myuros L.

Has characteristics of F. megalura.

20. Silver hairgrass *Aira caryophyllea* L. (*Aspris c.*) (L) (Nash)
Plants not hairy, dark gray green; blades folded in sheaths and when grown out, 0.5 - 0.8 mm. wide, 3 veined, rough on margins and veins of under surface, tips abrupt, pointed, turned upward; sheaths angular; ligules very conspicuous, pointed, 2 - 3 toothed, 1.5 - 3 mm. long, rough on outer surface, vertical veins absent; collars wedge-shaped, faint; margins of collars slightly bulging; lemma 1.5 - 2 mm. long, smooth, except for hairs at base; awn 2 - 3 mm. long, twisted, bent below middle, attached to lemma below middle of back.



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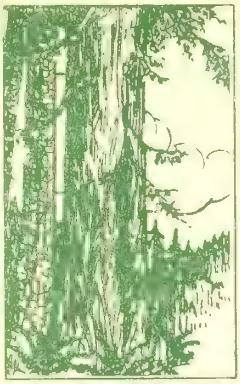

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

Research Note No. 28 December 1, 1942

A SITE CLASSIFICATION FOR THE MIXED-CONIFER SELECTION FORESTS OF THE SIERRA NEVADA

by

Duncan Dunning, Senior Silviculturist

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

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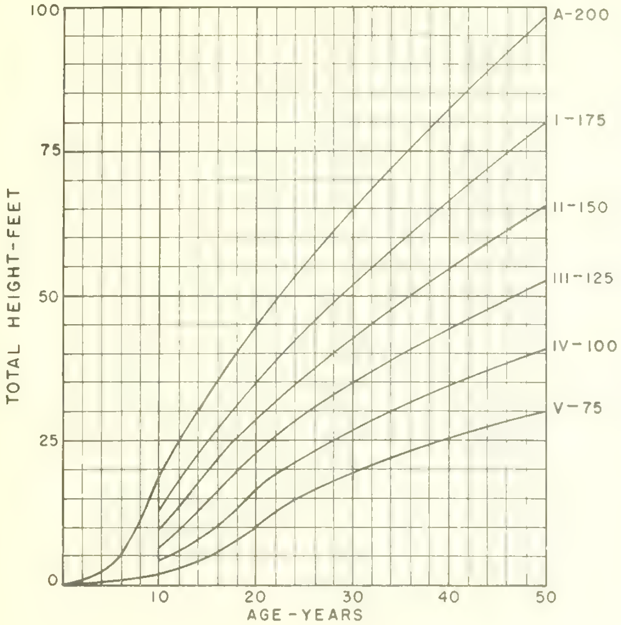


FIG. 1

Res. Note No. 28

A SITE CLASSIFICATION FOR THE MIXED CONIFER SELECTION FORESTS OF THE SIERRA NEVADA

1942

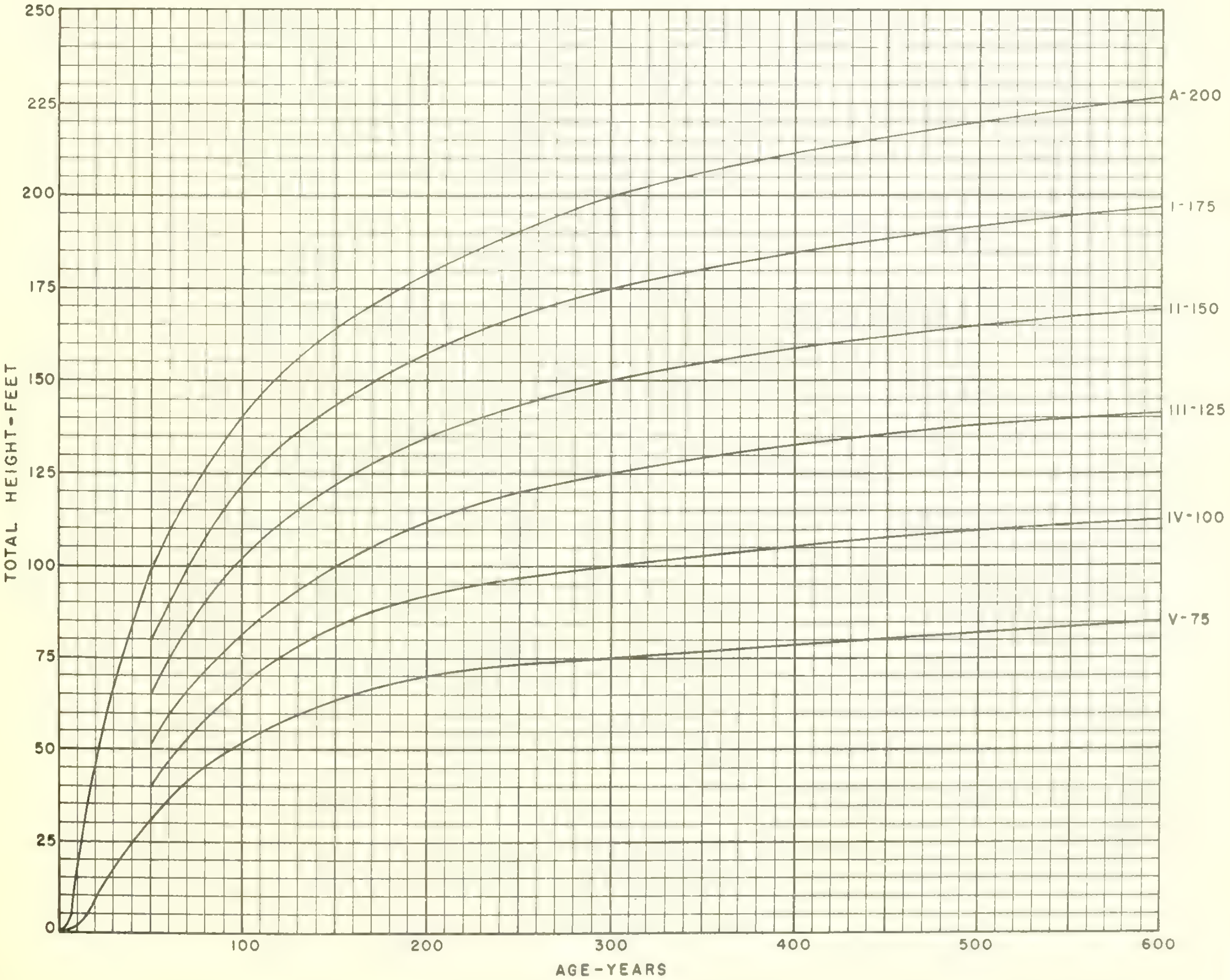
Duncan Dunning

CALIFORNIA FOREST & RANGE EXPERIMENT STATION

M. W. Talbot, Acting Director

Forest Service

U.S. Department of Agriculture



A SITE CLASSIFICATION FOR THE MIXED-CONIFER SELECTION FORESTS OF THE SIERRA NEVADA.

INTRODUCTION

Purpose

The site-class curves presented here as figure 1 for the irregular pine-fir forests of California were first prepared in connection with a yield-predicting procedure (1)[1] developed in 1933. The original curves were designed principally for administrative use of the Forest Service in Region 5. Since they have now come to be accepted by other agencies and for general purposes, this research note has been prepared to make the curves more readily available and to describe their peculiar features sufficiently to enable correct application. It is hoped that this action may contribute to the establishment of a single criterion of site for the region as nearly as possible like that most commonly used in volume surveys, growth forecasting, and other forestry work.

Basis

The height-age relationship here used as a basis for site classification, although widely accepted, is subject to numerous variations in practice. Adoption of standard methods of classifying forest sites was recommended in 1923 by a committee of the Society of American Foresters (2) under the chairmanship of W. N. Sparhawk, but this admonition has been rather generally ignored. Methods will probably never become widely standardized. Uniformity between regions having species in common, though much to be desired, appears to be impracticable. Within this region, where interdependent volume, taper, and yield tables are employed, a constant routine is necessary to prevent discrepancies between cruises, appraisals, and working plans.

Earlier Classifications

It is natural to inquire whether any site classification scheme already existed that might be acceptable. At least 7 site classifications had been developed for species in the territory prior to 1933, and there are now about 12, in addition to the present one. Most of these classifications are useful under special conditions rather than for the region as a whole. All but one divide the territory according to scales based on the height of a single species, usually growing in young, even-aged stands. The single exception (3) for mixtures is limited to young, even-aged stands.

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[1] Numbers in parentheses refer to Literature Cited, p. 20.

[illegible] used to such an extent as to affect a substantial body of records and plans. This scheme [illegible] with Bruce's (4) proposed classification for white fir volume tables. Modifications in use by the Forest Service adapted the scale to other species. Following the introduction of the site class volume table by Bruce in 1921, many forestry records came to be grouped by site class. In the present instance, the aim has been to avoid invalidating these expensive volume and yield tables, working plans, and other records by retaining the essential features of the two existing old growth and young growth classifications for mixed stands.

The Proposed Classification in Brief

The curves define the midlines of six site class zones; are harmonized to intercept 25 foot intervals in a height range of 75 to 200 feet at a reference age of 300 years; and are based on 20- year age-class averages in the total height of dominant trees of one or more of the species sugar pine (Pinus lambertiana), ponderosa pine (P. ponderosa), Douglas fir (Pseudotsuga taxifolia), and white fir (Abies concolor).

FIELD AND OFFICE PROCEDURE

Data

Records collected for other purposes were used as the basis for the site class curves. Naturally these measurements are not an ideal sample of the wide range of conditions in the California pine region. From numerous data collected between 1902 and 1929, those groups have been selected that seemed most representative of the site range in the commercial timber belt, giving greatest weight to the measurements on which our principal volume and yield tables are based.

Second growth

The principal second growth measurements came from 220 sample [illegible] stands. These plots were small, averaging about one fifth of an acre in area. They represented stands of the three upper site classes with ages ranging from 40 to 125 years. Ninety percent of the plots were less than 80 years old. The stands were characteristic of the better portions of the western slope of the Sierra, the majority being located in the Feather and Yuba River drainages. Types represented six of the commonly occurring mixtures of ponderosa pine, sugar pine, Douglas fir, white fir, red fir (Abies magnifica), and incense cedar (Libocedrus decurrens).

Old growth

Reliance was placed mainly on the old growth or virgin forest records included in the seven groups described in table 1.

Table 1. Old growth data used in preparing site class curves of figure 1

Site	Trees	Species	Location	Date
I	247	Ponderosa pine, sugar pine, white fir	Cow Creek, Stanislaus N.F.	1924
I	535	Ponderosa pine, sugar pine, white fir	Shearing Cr., " N.F.	1929
II	519	Sugar pine, white fir	Granite Basin, Plumas N.F.	1924
II-III	288	Ponderosa pine, sugar pine, Douglas fir, white fir	Massack, Plumas N.F.	1912
III	759	Ponderosa pine, Jeffrey pine	Westwood[2], Lassen N.F.	1913
III IV	138	Ponderosa pine	Lasco, Lassen N.F.	1925
IV	561	Ponderosa pine, Jeffrey pine, white fir	Lemon Canyon, Tahoe N.F.	1924

Three of these groups of measurements - those from Cow Creek, Westwood[2], and Lemon Canyon - are of special interest because they defined the three principal guide curves for the system

The groups of old growth tree measurements came from areas differing considerably in size, suggesting the possibility of greater site variation within some groups than others. Most of the field notes give locations only to the nearest land section, whereas distribution of the trees may have been limited to tracts as small as quarter sections or even 40 acres. To be remembered also is the tendency for sugar pine and white fir to predominate on northerly slopes and bottoms, whereas ponderosa pine would be encountered more frequently on the comparatively poorer southerly slopes and ridges. Of the species considered here, all four were present in only one group. Ponderosa pine was best represented in number of trees. Few records were available for the best and the poorest site classes. Personal knowledge of the several localities and the records leads me to believe that none of the chosen groups embraces a range of variations in excess of the regional concept of a site class.

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[2] Made available by M. B. Pratt, State Forester of California.

[illegible]

[illegible]

[illegible] as felled in logging. Trees with abnormal tops or incomplete height records were rejected. Ages were determined from ring counts made on the stumps, with the uniform addition of 7 years as an allowance for time to reach stump height. This uniform allowance seemed justified by stem analyses indicating that truly dominant seedlings vary but little with site in the time required to reach stump height. In preparing the guide curves, tree measurements were rejected where stump rot or fire scars necessitated additions of more than 5 years to the number of rings visible. The trees ranged in age from 74 to 660 years, but only about 6 percent of the 3,047 used were less than 100 years old. The form of the curves for young trees offered the most difficulty, and numerous supplementary measurements from permanent sample plots and other sources were used to aid in reaching decisions.

[illegible]

In constructing the system, the uppermost curve was derived [illegible] anamorphosis [illegible] For Site II, several groups of data produced widely differing curves. The final [illegible] between the two slightly differing curves derived by anamorphosis from the Site I and Site III guide curves. The Site V curve was derived from the guide curve for Site IV

Choice of the Site Scale

[illegible]

Choice of the site range for the region was necessarily a somewhat arbitrary procedure based on practices already proved to be convenient and useful, but probable future requirements were not completely ignored. The prevailing concept of site range has been strongly influenced by cutting practices in old growth stands on national forest lands since about 1906. The best sites, however, are in private ownership, and the very cream of the private old growth timber doubtless was logged prior to 1906. More recent studies of yield and measurements of piling in second growth that followed logging between 1860 and 1880 show clearly that there is much forest land better than that we now designate as Site I. Increasing activity in these second growth areas, as well as greater interest in forest practices in the better private old growth, makes it desirable to start the site scale at a higher level than the present standard, 175 feet at 300 years. A fairly definite reference point at the top of the range is the maximum height thus far measured — 246 feet for sugar pine. The average for the upper limit should be placed enough lower than this absolute maximum to insure inclusion of a reasonable portion of the territory in the first class. This average has been set at 200 feet at 300 years. A new site class thus is introduced. At the lower extreme the generally accepted poorest site limit of 70 to 80 feet for commercial timber seems to be about right. The average for the lowest class, therefore, has been left at 75 feet.

Number and size of classes

Classes previously used. The number and size of the classes into which the site range is divided also reflect deference to locally established practices. In the first working plan for the region, Barrington Moore (6), in 1913, considered only three site classes necessary for the Plumas Working Circle. Show (7), in 1925, for the Eastern Lassen Working Circle, recognized five sites defined by 20 foot intervals in a range of 70 to 170 feet in the maximum height of old growth ponderosa pine. In more recent yield tables for second growth, as many as 10 site index classes are recognized, usually based on 10 foot height intervals at 50 or 100 years. In national forest timber management, five site classes, based on 25 foot intervals, have become rather firmly established, perhaps because seven of a proposed regional series of volume tables (8) prepared between 1921 and 1925 were related to this scale.

Effects on existing site class volume tables. The relation between tree form and site, which suggested the site class volume tables, is not as simple and direct as expected. Partly for this reason, tables for the poorer site classes were never constructed to complete the regional series, but a new series, range wide in scope, was constructed in 1928, under Bruce s direction, for ponderosa pine. The site range in this series was divided on the basis of merchantable length in 16 foot logs. Unfortunately, the intervals were not readily adapted to local work, and the new tables for the better sites were not generally accepted, the local ones continuing in use. The need of tables for the poorer site classes gradually became critical and, as an expedient, the Site IV and Site V ponderosa pine tables of the 1928 range wide series were adopted for local Forest Service timber surveys (9).

Range wide site class volume tables also were prepared for Douglas fir by Meyer (10) in 1932. No consistent relation between form and site was apparent in the extensive Douglas fir records, which included some 7,000 trees from 85 locations. As a consequence, Meyer made separate tables for only two divisions of the Douglas fir range - the Cascade Range and the coast region of the Pacific Northwest, combining Sites I, II, and III; and the more inland distribution of the Sierra Nevada, the Blue Mountains, and the Rocky Mountains, embracing Sites IV, V, and VI. The California records all fell in Site IV. The site class scale in this case was the one previously used by McArdle and Meyer (11) for second growth Douglas fir - 30 foot intervals in the average height of the dominant and codominant trees at 100 years. This scale, also, was at variance with California custom, and local practitioners continued to use an earlier favorite, a general California table constructed in 1911.

Use of one table for all sites also remains the rule for old-growth incense cedar, red fir, and some other species. Adding to the confusion, numerous tables have been prepared and used for second-growth of all species without reference to site. There are in the region approximately 90 volume tables for various species, age classes, products, and standards of utilization that are still considered of some utility. Also, there are numerous taper tables, some prepared without regard for volume tables derived from the same measurements, so that volumes calculated from the tapers differ from the volumes computed from the tables.

The confusion prevailing in the volume table situation is a natural consequence of much uncoordinated work by numerous persons and agencies. Work on volume tables, even though uncorrelated, probably will continue, one reason being that appraisal methods require more properly related volume and taper tables. The attainment of some semblance of order is a remote possibility contingent on support for a comprehensive fundamental study of tree form. Until general revisions based on some unity of principle can be undertaken, further confusion will be avoided by maintaining the present site-class scale.

Relation to yield; even-aged stands. Yield and growth properly should determine the site scale. The presumed form-site relation was able to usurp this prerogative because, until recently, yield tables were based on young even-aged, normal stands. There being little of such timber in California, and only minor use of what exists, the tables and site scales received little attention. Growth records are now available for the more characteristic understocked forests with great range in composition and age.

Relation to growth; selection stands. Records in such stands covering a period of 20 years show the usual strong correlation between annual growth in board feet and site quality, amply justifying distinction of several site classes. By chance, these records support retaining the size of the classes already used in connection with volume tables, for they show that differences in growth are not significant for intervals smaller than 25 feet at 300 years. The growth records for selection stands obviously do not cover the entire site range, and it has been necessary to rely on the more comprehensive height data in fixing the number of classes at six.

Relation between young- and old-growth scales

The possibility of easy cross-reference between young- and old-growth sites is an important consideration in selecting a site-class scale. Unfortunately, the curves of a site-class system are not so simply related as to permit direct reference by graduated intervals from one index age to another. The difficulties, as encountered in young plantations, were discussed by Bull (12) in 1931. The present curves, adjusted to a constant interval of 25 feet at 300 years, intercept intervals varying from 16 to 21 feet at 100 years, and 10 to 17 feet at 50 years. Conversely, if adjustment is made to the most commonly accepted interval of 10 feet at 50 or 100 years, the intercepts vary at maturity.

Perhaps a desirable ultimate solution of the difficulty would be to abandon the equal interval. Presumably the most logical objective of site distinction is to group lands into equal classes of yield capacity. Sparhawk's committee recommended equal subdivisions of the mean annual growth range at age of culmination. Usually this would mean letting the height intervals vary. The prevailing practice of grouping yield plots according to a uniform height scale imposes unequal differences in tabular yields for even aged stands. In such stands, a given increase in site index is accompanied by a greater increase in yield near the middle of the range than in either the upper or lower portions. In our mixed selection stands, however, periodic annual growth in board feet per acre fortunately does show an essentially straight-line progression with change in site, a circumstance admitting equal intercepts for both growth and height scales.

Site class versus site index

The tendency to favor equal height intervals probably is a consequence of adhering to the principle of the site index in preference to the site class. Equal spacing of the curves simplifies reading a site index scale in feet. But acceptance of the index principle tacitly invites site distinctions to the nearest foot with the implication that such fine subdivisions are practical and useful. At best, site determination by height indicators is the result of a series of approximations based on personal judgment, and neither great accuracy nor consistency is to be expected. Although small differences in average height can be detected by increasing the intensity of sampling, the greater cost involved is not justified by [illegible] in accuracy of the growth forecasts, for the reason that height index explains only 18 per cent of the variation in growth in these selection stands. For most present day forestry purposes, classes corresponding to about 10 feet at 50 years, 15 feet at 100 years, and 25 feet at 300 years may be small enough. The scale proposed here probably comes as near as can be expected to providing such classes.

Reasons for 300-year reference age

Disadvantages of tallest tenth as reference. The index age of 300 years has been adopted for a number of reasons. The former criterion for old growth was the average height of the tallest 10 percent of any trees measured. This was based on the assumptions that the trees of the upper tenth would be dominants; that they [illegible] growth; that 10 percent would be enough for a good average; and that the upper tenth [illegible] for a more discriminating selection of dominants, notably for culled or cut over stands. Also, the taller trees automatically selected varied in age from about 200 to over 600 years, and in this age range the height increase is enough to cause errors of a site class. As to reliability of the sample average, 10 percent of whatever number of trees happened to be available might be enough, too few, or too many, with accordingly undesirable variation in the reliability of the site determinations. Finally, selection of the upper tenth always results in classifying the site too high because the sample includes only the exceptional trees growing in the most favorable situations — lower slopes, flats, and depressions — not representative of the entire tract. The tallest tenth criterion, therefore, was abandoned in favor of the average dominant of determined age.

Curve position shifted to middle of zone. While making this change, it was important to retain the familiar concept of the site classes and to avoid revising volume and other tables. When age height curves were drawn for the dominant trees on which the volume tables are based, it was found that these curves intercepted approximately the recognized site class limits of 75, 100, [illegible] 175 feet at [illegible] ranges [illegible] found [illegible] intercepts [illegible] should be noted that the change in reference from the tallest tenth to average height at 300 years resulted in shifting the averages for the site [illegible] downward. Thus, Site II, instead of lying [illegible] at maximum ages with average about 162, now [illegible] at 300 years, with average about 150 feet.

Mature dominants less variable than young. The 300 year reference age also was favored because of the fact that height age curves are extremely variable in form through the early age classes including [illegible] of 50 or 100 years that have grown [illegible] competition. The upper site index curves derived exclusively from young dominant trees, especially from even aged optimum stands commonly chosen for yield tables, apparently show absurd trends towards impossible heights at older ages. Certain groups of trees in the present data that fall [illegible] 300 years or older would fall in three sites on the basis of the 100 year dominants and in four sites with reference to the 50 year dominants. Comparisons of the height deviations by age classes show that the within group variation is no greater for the younger than for the older dominants. The inconsistencies could result from inclusion of more than one site class in a group with the age class distribution restricted by site — a very improbable coincidence not supported by observation, as mentioned before. The vagaries in form of the lower sections of the curves apparently reflect between group variation in stocking and competition. In the limited instances where yield tables for even aged stands can be applied, the special site index curves on which the tables are based should be followed without attempting to translate one scale into another. In the more frequently encountered irregular stands, the choice of older trees near the 300 year reference age should avoid the larger, between group variations.

Disadvantages of high reference age can be overcome. Disadvantages of the higher reference age are the scarcity of well-formed older dominants, especially in cut over stands, with the chances in favor of their becoming even fewer, and the difficulties of determining the ages of large trees. Although selecting sample trees near the 300 year age class where possible will result in classifying sites most nearly in harmony with present concepts, where only younger dominants are available, no greater errors should result in selection stands from use of these curves than from curves referenced to 50 or 100 years As old growth declines in importance, concepts of site doubtless will change under the influence of increasing familiarity with yields at the lower rotations, whereupon currently used tables, as well as site graphs may be abandoned.

Where practicable, the site class should be determined while felling is in progress so that age counts on the stumps and the corresponding height measurements on the larger trees can be made without having to use either the increment borer or the hypsometer. A land subdivision record of all site determinations, perhaps on a key map, would prevent discrepancies arising from the personal variable or cutting and other stand changes and would insure constancy of the old growth datum

Designations validate existing titles

The designations decided upon for the site classes require explanation. Consistency in the endeavor to avoid confusion with respect to existing tables and records requires that titles and terminology be maintained in effect. The newly introduced highest site class, therefore, has been designated "Site A" in order to retain the present significance of Sites I, II, V. Both the Roman numerals and the average heights corresponding to the classes have come into common use. Since neither one alone is sufficiently descriptive, it is suggested that both be included. Thus, from best to poorest, the classes become Site A 200, Site I 175, Site V 75. Sample averages should not be reported to the nearest foot but should be given the site designation of the curve nearest along the ordinate for the age, differences of less than half a site class being ignored in application.

APPLICATION

The characteristics of the data and the methods of construction as described above should be relied upon mainly as a guide to application of the curves. Something additional needs to be said respecting limitations of territory, types, stands, and sampling procedure.

Territory Covered

Although these curves are founded mainly on trees that grew on the west slope of the Sierra Nevada, they should be applicable to other sections of the so-called pine region such as the east slope of the Sierra; the Warner Mountains; the volcanic plateau in northeastern California; the Cascade System south of the California border; and the northern inner Coast Ranges. The humid coastal redwood region and the boreal spruce-fir types of the northwest coast contain Douglas fir, but the trees there grow on a grand scale not matched on sites of the interior.

Forest Types

In applying this site classification the term "mixed conifer" in the title is to be interpreted freely to include the multiple combinations of ponderosa pine, Jeffrey pine (Pinus jeffreyi), sugar pine, white fir, Douglas fir, and incense cedar, and the limited, nearly pure stands formed by some of these species.

Character of Stands

Selection and even aged

The curves are intended primarily for the so-called selection stands wherein the age classes are usually represented by tree groups of varying size. For extensive general surveys and comparisons they should be suitable also for the even-aged stands encountered. True even-aged stands are comparatively rare and are usually of small extent. For the more important of these exceptional stands, special yield, volume, and site-index tables are available and should be used.

Cut-over stands

Some rather meager records support the belief that curves based on dominants reserved after light or moderate cuttings will have the same form and will yield the same site-class values as curves based on the original stand. This apparently is not true where cutting was heavy and the reserve is less than 20 percent of the original volume.

Density of stocking

Density of stocking in relation to site determination merits careful consideration. Height growth is normal in moderately stocked stands and is appreciably subnormal in both extremely dense and very open stands (13). Complete dependence on the height index unavoidably results in confusing, to some extent, variations in stocking with changes in site quality. This probably explains, in part, the anomaly apparent in normal yield tables -- the progressive increase in number of trees to the acre for a given age class as site quality decreases. Safe limits in the range of normal stocking for site determination cannot be specified for selection forests. The only normal density indices available are for even aged stands and, as suggested above, these indices themselves are dependent on the height scale. Also, the degree to which extremes in density affect height growth is not known, even approximately, for any of our species. Furthermore, it is often not enough to know age and density at the moment of site determination the history of stand treatment also is important. For example, thinly spaced dominant trees, isolated but a short time by cutting, provide satisfactory indicator samples, whereas long isolated or naturally sparse trees do not.

Thus success in selecting height samples that are reasonably free from the influence of abnormal density depends mainly on individual experience and interpretation. Extremely dense, stagnated stands as well as extremely thin orchardlike stands can be avoided. The younger groups and stands in the throes of competition are perhaps most sensitive to overstocking, are most variable, and hence, least reliable. Sampling several age groups is desirable and, when disparities are obvious, the site indicated by the older groups is to be preferred.

Sampling

Importance

Obtaining sample indicators that are satisfactory for subdividing land into site classes deserves more thought and planning than are commonly devoted to the procedure. Errors and inconsistencies are prevalent and of serious proportions. Adherence to the long recognized fundamental principles of sampling would prevent the more serious mistakes. Beyond this, few special procedures can be recommended for the reason that the form of distribution of site quality and the factors controlling it are not well known. Two aspects of the sampling problem are discernible the one having to do with size, shape, and other characteristics of the land subdivisions, or getting good averages for the site qualities; the other concerned with behavior of the indicator species within a given site quality. Less is known about the land aspects somewhat more about the trees.

Prescribed conditions

For larger tracts, it frequently happens that the nature of the subdivisions for which site ratings must be made is unknown until after an extensive survey is completed. Type, age class, and other boundaries may be fixed by mapping as the survey progresses, or may not be determined until after the notes are compiled. In such cruises, the site indicator measurements are taken concurrently with the stock and other data. With these prescriptions, the best that can be done by way of planning is to insure enough records of adequate distribution for the most exacting of reasonable subdivision schemes.

Small plot work introduces the simpler problems in site determination. Here the land aspect merges with the indicator phase about which most is known, for there is little chance of a small plot's containing more than one site quality, and age classes and types are restricted. It is necessary only to sample the indicator trees. These are the conditions represented by our basic data. A study of variation therein serves as a guide to the number of trees that should be measured. With due allowance for height-age regression, 5 to 15 trees are enough to determine the site correctly 19 times out of 20.

Areal unit of sampling

A sampling procedure is suggested by the simplest case of the small plot. If we can agree upon the dimensions of some small plot to use as a standard, or sampling unit of site quality, the indicator can be sampled within these units by taking 5 to 15 trees in each, as noted above.

The sampling unit should be small enough to avoid including too frequently more than one site. Too small a unit in open stands frequently would not include the minimum of 5 indicator trees. Very small plots also would multiply excessively the number of tree samples required. Experience in plot work shows that square tracts up to 10 acres in area, with site range less than a class interval, are of common occurrence even on variable topography. Twenty- to 40-acre plots are fairly easy to find on the more uniform northeastern lava plateau. Twenty acres is the smallest unit for which it would be practicable to keep separate notes in cruising by the usual 10-percent coverage. The long, narrow shape of such 20-acre plots is not ideal, but it would seem better to accept this unfavorable feature than the large size of 40 acres, the first convenient square. Units of 20 acres can be combined exactly for most subdivisions conforming to public land lines, and with compensating nonconformities for irregular subdivisions. It is suggested, therefore, that the 10 x 20 chain, 20-acre tract be accepted as the areal sampling unit for site quality and that the indicator sample be selected on the 1 x 20 chain strip in each unit.

Selecting areal and indicator samples

The ordinary timber cruise is a systematic survey. The advantages in economy and accuracy of systematic strip sampling have been demonstrated for determining volume (14) and area of irregular types (15), and by inference, the same system should be satisfactory for collecting the areal, or site quality sample units. With regard to the indicator sample, any routine adopted should favor randomness with respect to age classes and species as well as uniform distribution along the strip. These conditions probably would be satisfied approximately if the one most suitable tree nearest the compass line were selected in each 4 chain interval of a strip. Schumacher and Chapman (16, call attention to the bias in favor of open-grown trees introduced by this method of selection. For present objectives, the averages probably would [illegible] would be counterbalanced to some extent by suggested precautions to insure dominance and moderate stocking.

Choice of true dominants

The sample trees should be true dominants (17) relative to other trees of the same age class. If the Region 5 tree classification (18) is followed, the trees should be from classes 1, 3, or 5. The term "dominants" should not be construed to include codominants, as sometimes is the practice. The admission of codominants was favored by Sparhawk's committee. The inclusion of codominant trees incurs the additional obligation of insuring representation of the two crown classes in the sample in the same proportion as they occur in the stand on the sample area. It is not practicable to do this concurrently with cruising mixed, group selection stands where the proportion changes rapidly with age, composition, and stocking. For cruises made with the intention of using the locally developed growth predicting mechanism, only the dominants need be distinguished in the records; hence reliance on this crown class for site indicators avoids a special tally. The dominants are usually easy to recognize, whereas the admission of codominants is conducive to quibbling over marginal trees and leads to inconsistencies in site classification. Since the codominants compensate in no way for their disadvantages, nothing is lost by their exclusion. Decision as to dominance is simplified by picking the trees from groups. Here the crown class relation is most obvious and there is apt to be evidence indicating whether dominance and moderate stocking have prevailed from the beginning.

Age determination

Determining ages of the sample trees can be reduced to a simple procedure practicable even for most cruising. This is true because relatively large errors in age of 12 to 50 percent introduce small risk of missing the site class; consequently the number and length of borings for ring counts can be reduced considerably by resorting to partial or complete age estimates.

Permissible errors. The range of error in age admissible without missing the site class increases with increasing age and with decreasing site quality. Because of the form and relation of the curves, negative or low estimates of age are more to be guarded against than positive errors. As a rough guide, the maximum allowable negative departures from certain age class averages are shown in table 2

Table 2. Maximum negative departures from age class averages allowable without error in site determination.

Site class		Age class, years			
		50	100	200	300
		Negative departures, years			
A	200	6	16	35	65
I	175	6	15	40	70
II	150	6	15	40	75
III	125	6	16	45	90
IV	100	7	16	50	110
V	75	9	20	70	150

Age from borings at breast height. For trees 100 years old or younger, where ring counts will usually be necessary, the radii will fall within the span of the increment borer except on the best sites. For the larger trees, counts from the longest cores attainable may be supplemented with estimates for the remaining sections of radius. This will involve attention to such details as measuring diameter, single bark thickness, and core; calculating the remaining section of radius; estimating the rings therein; and adding estimate and core count.

Age counts from borings at breast height must be converted to total ages by adding the number of years required to grow to the height of 4.5 feet. The time varies from about 6 to 16 years according to site, but to make a variable adjustment would require an undesirable preliminary estimate of site quality itself. It would seem least prejudicial to the final estimate if a constant conversion factor, such as 10 years, [illegible]

Age estimates. When refinements are not advisable, where the timber is very large, or for other reasons estimates of age must be relied upon entirely, indicator trees should be favored that are near the reference age of 300 years where errors of 20 to 50 percent are permissible. If circumstances require using the average height at the estimated mean age for a whole tree class, class 3 or class 5 is to be preferred. It is sometimes the practice to enter the curves with the average height of the class 3 trees at the 300 year upper limit instead of the average age. This may result in missing the site class if the quality is high. In one instance of record where tree classifications and age determinations were made independently on the same large trees, 32 class 3 pines averaged 251 years old, and 158 class 5 pines averaged

348 years. When resorting to estimates of age, it is well to remember that ponderosa pine and sugar pine are less deceptive than white fir and Douglas fir. Errors were compensating for the pines but tended to be positive for the other species.

Species indicators compared

All four species apparently may be used safely, without distinction, as site indicators. It should be noted that this conclusion is contrary to earlier recommendations. Schumacher (19) in his study of white fir yields, concluded that sugar pine dominants in even-aged stands 45 to 150 years old were shorter than dominants of the other species by 2 to 8 percent. The earlier study (3) of mixed, even-aged second growth, based partly on Schumacher's plots, apparently affirmed this conclusion, disparities being reported as large as 10 percent. Results of the present old-growth study, more recent information from permanent plots, and review of the earlier second-growth records lead me to believe that the conclusion is incompatible with behavior of the species and that a distinction between them is not justified.

The records for the older timber used in this study show that sugar pine is, if anything, slightly taller than the other species at comparable ages, but the differences between the four species are not large or consistent enough to be accepted as significant or important.

Regular observations of numbered trees over long periods indicate that sugar pine, once behind in the race with fir, continues to decline if unassisted. Superior trees in older stands usually have been dominant from the first or were released early in life. It is well established by thousands of measurements that sugar pine in mature mixtures does attain maximum heights above any of its common associates. This fact is not to be interpreted as proving its ability to outstrip other trees in fair competition, for the tallest sugar pines exceed in age the tallest trees of the other species from a few to as much as 140 years.

The inferences that might be drawn from uncritical comparison of the second-growth and old-growth records have important management implications. If it were true that sugar pine, even though subordinate in young stands, could improve its position, eventually becoming dominant by surpassing in height growth such competitors as the more tolerant white fir, our whole concept of mixed-stand silviculture would have to be revised. The unnaturalness of the conclusion that the comparatively intolerant pine could be consistently shorter than fir and still be dominant suggested some fiction in the crown classification. This suggestion was supported by the recollection that the dominants were to be the tallest trees by specification; hence, an impartially selected fraction of them could not logically average 10-percent shorter than the whole. For these reasons, instead of adopting the simple expedient of omitting sugar pine from the site sample, the second-growth records were reviewed.

This review indicated that the apparent disparity in height between the species resulted from an inadvertent bias in the field methods used in the mixed second-growth study. This bias entered through unintentional shifting of the criterion of dominance between the species. The intention was to measure heights for the dominants of average diameter. Unfortunately, in practice the diameter of the average dominant was taken independently for each species rather than for all on the plot as a whole. This procedure operated to the disadvantage of sugar pine, because this species was nearly always a minor component of the stands and, in the 50 to 60 year age-class where most of the plots were concentrated, was beginning to suffer severely from competition with fir. Thus, sugar pine was poorly represented in the upper range of diameters. As a consequence, failing sugar pines of smaller average diameter were pitted against larger firs higher in the scale of dominance. When a comparison was made for 61 plots representing age classes of from 45 to 125 years, where heights of all species were measured at the same points in the range according to the criterion of equivalent diameters, sugar pine dominants averaged 87.0; ponderosa pine, 86.2; Douglas fir, 83.2; and white fir, 84.7 feet. These differences are not large enough to excite serious concern in making the rather general site distinctions contemplated. Evidently the species may be averaged together provided the definition of dominance is applied impartially.

Incense cedar, an almost constant associate of the four species discussed here, often exceeds the others in numbers but is always inferior to them in stature. On cut-over land where defective cedars are sometimes the only remaining trees, one should not place dependence on this species as a site indicator.

Accuracy of measurements

Height measurements should be made within reasonable limits of instrumental error perhaps about 2 percent. This can be accomplished easily with the Abney level and tape.

Indicator trees to be of normal form

Trees with normal undamaged tops should be selected for the sample height measurements. The choice need not be restricted to trees with pointed crowns. Older round or flat-topped trees are admissible where the condition results from natural decline in height growth rather than from forking, breakage, or mistletoe and insect damage.

[illegible] required

The numbers of sample trees necessary for averages of specified reliability are approximately equal for the several site classes. With respect to age, because of varying width of the site-class bands, the numbers required decrease rapidly from 50 to 150 years and are then fairly constant to higher age classes. The figures in table 3 for Site I - 175 and Site III 125 are indicative of the numbers of trees necessary for all sites at various ages to insure averages that will fall in the proper site-class zones 19 out of 20 times. These numbers are to be considered as minima where ages are known within limits of 1 to 5 years.

Table 3.- Number of sample trees required for height averages indicating the correct site class 19 times in 20.

Site	Age class, years								
	50	100	150	200	250	300	400	500	600
	Number of trees								
I - 175	14	11	8	7	7	6	6	5	5
III - 125	18	10	9	6	5	5	5	4	4

Calculating the indicator average

In combining measurements for a general site indicator, decision as to the site class will be expedited if weighted averages are used instead of curves plotted from the sample trees. Weighting should be accomplished through reference to figure 1 by multiplying the height in feet of the nearest curve at reference age 300 by the number of trees in the site-class zone. The combined indicator should be reported by the designation of the nearest site-class curve rather than by the actual average in feet. For example: If the ages and heights of the sample trees on a 20-chain strip were 100 years x 80 feet, 210 x 122, 200 x 127, 255 x 112, and 105 x 90, the indicator average would be

$$\frac{(4 \times 125) + (1 \times 150)}{5} \quad \text{or}$$

130 feet, and the site class would be reported as III-125.

Merchantable length not a substitute for total height

Merchantable length, or height to a fixed top diameter, is frequently used erroneously in computing site indicators. A common fault is to convert the number of 16-foot logs to feet, add some number for the average length of top above the fixed diameter, and use the sum for reference to site-class curves based on total height. The trouble with this procedure is that proper average additions for top length are practically indeterminate. The top section varies with species, top diameter, merchantable height, age, diameter at breast height, and with the object of estimate — site quality. The attempted correction therefore implies a prejudicial advance estimate of site. A related mistake is to use interchangeably site-class scales in equal intervals of merchantable length and equal intervals of total height.

It may be supposed that one could prepare merchantable height curves intercepting variable intervals at the reference age and so correlated with the equal-interval total height curves as not to change the concept of site in terms of predicated yields. One objection to this proposal is that for mixed stands more than one set of curves, perhaps one for each species, would be necessary.

The use of merchantable height for site reference in any manner is probably at variance with the height-indicator principle. Resort to the utilization standard implies a shift in the biological concept of crown class and involves a departure from the definition of dominance. Regardless of apparent convenience, converting one standard to terms of the other is an unsound procedure. In the long run, it will be found more efficient, more consistent, and more nearly accurate to measure the total heights in the field especially for site determination.

Site Classification Is Justified as a Special Project

In truth, where land is not already well classified, making site determination a special undertaking will pay dividends in better forest management. Sharp distinction of the more productive areas will aid in correcting the prevailing almost indiscriminate distribution of effort to the good, the poor, and the indifferent soils alike which characterizes the poor management of pioneer forestry. Dispersal of forces -- a little everywhere but nowhere enough -- cannot stem the tide of drain from fire, insects, disease, brush invasion, and improvident cutting. Intensification of forestry can be accomplished at no greater cost by localizing the effort. Site classification will show where.

SUMMARY

Site classification curves are presented (figure 1) for the mixed-conifer selection forests of the California pine region, with enough description of data and methods of preparation to enable correct application. The object is to establish a single criterion of site as nearly as possible like the one now in use for volume surveys, growth forecasting, and other forestry work.

The classification is based on the height-age relation for dominant trees of one or more of the four species, ponderosa pine, sugar pine, Douglas fir, and white fir.

The site range is divided into six classes represented by 25-foot intervals of average total height of true dominants at a reference age of 300 years. This scale divides the range in production capacity by equal intervals of periodic annual growth.

The site classes are designated, from best to poorest, A-200, I-175, - - V-75. The curves define the midlines of the site-class zones.

The territory covered includes the Sierra Nevada, the lava plateau in northeastern California, the Warner Mountains, the Cascade System south of the California border, and the northern inner Coast Ranges, but not the redwood or northwest coastal sections.

Types for which the curves are adapted include varying combinations of ponderosa pine, Jeffrey pine, sugar pine, white fir, Douglas fir, and incense cedar, and the limited, nearly pure stands formed by some of these species.

The classification is intended primarily for the irregular, grouped selection forests but for general plans and surveys may be applied to the occasional even-aged stands encountered. It is unsuitable for extremely dense stands or stands that have always been extremely open. It can be used on cut-over land with moderate to heavy reserves where some true dominants are left.

To obtain the general site class for a large tract it is suggested that areal sampling units not larger than 20 acres be taken systematically. A minimum sample of 5 trees, obtained by measuring one well-formed dominant near the reference age for each 4 chains of strip, apparently would give the correct site class for the areal unit 19 times in 20.

The number of sample trees of determined age per areal unit required for height averages in the right site class 19 out of 20 times varies from 15 at 50 years to 5 at 300 years. Heights should be measured with an Abney level and tape. Ages should be determined to the nearest 5 years if the trees are around 50 years old, but errors as large as 60 years are permissible if the trees are 300 years old or older.

Merchantable heights to a fixed top diameter cannot be converted satisfactorily for reference to this site classification.

Site classification, by showing where to localize effort, contributes to intensification and greater efficiency in forest management.

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FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

Research Note No. 29 March 15, 1943

PRELIMINARY ESTIMATE OF PRODUCTION OF LUMBER, LATH, AND SHINGLES IN CALIFORNIA, 1942

In cooperation with the Bureau of the Census, U. S. Department of Commerce, and the War Production Board, the Forest Service presents herewith its annual preliminary statement of lumber production in California and Nevada. Since this statement is based upon incomplete returns it will differ somewhat from subsequent final production statistics to be compiled by the Bureau of the Census.

The estimate of 1942 production shows that the lumber industry in California, despite adverse effects of manpower and equipment shortages and bad weather in the spring of 1942, responded to the unprecedented wartime demand for lumber by producing only a fraction less than was sawed in the all-time peak year of 1941.

The production estimated in tables 1, 2, and 3 is based upon reports from 207 of an estimated total of 239 active sawmills in the California pine region and on 59 of an estimated total of 75 active mills in the redwood region. The coverage was such that in the pine region the sampling error of estimated total production, expressed in percentage and based upon ± one standard error, was 0.2, while the corresponding error in the redwood region was 0.5.

For the entire State and all species, the estimated production of 2,322,170 M feet b.m. (table 1) is only 0.4 percent less than total State-wide production in 1941. With the exception of redwood, Douglas fir, and white fir there was a decrease in the cut of all species ranging from a 2.7 percent decline in incense cedar to a 19.3 percent decline in Sitka spruce. The most significant decreases were the 3.7 percent decline in ponderosa pine and the 12.6 percent decline in sugar pine. Although the production of redwood rose 1.1 percent from 1941, the most outstanding increases were a rise of 40 million feet in the cut of Douglas fir, equivalent to a 16.2 percent increase, and a rise of 30 million feet in production of white fir, equivalent to a 30.1 percent increase. The estimated production of lath and shingles declined 5.2 percent and 35.7 percent, respectively. Lumber stocks dropped from 846,854 M feet b.m. on December 31, 1941, to 616,441

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

M feet b.m, on December 31, 1942, or a decrease of 27.2 percent. It is estimated that there were 103 idle sawmills in the State in 1942, most of which were of low potential output.

In the pine region the estimated lumber production in 1942 was 1,730,931 M feet b.m. (table 2), or approximately 3 percent below the output in 1941. There were declines in the output of ponderosa pine, sugar pine, incense cedar, and big tree, but increases in the production of Douglas fir and white fir. The sampling error for species production was less than 2 percent for all species except incense cedar and big tree. Lumber stocks declined about 140 million feet in 1942. The 44 mills which cut more than 10 million feet apiece produced 86.8 percent of the total lumber sawed in the region, whereas the 131 mills producing less than 1 million feet each cut only 2.1 percent of the regional production.

In the redwood region the estimated 1942 lumber production of 591,239 M feet b.m. (table 3) was approximately 9 percent greater than the 1941 output. The most outstanding development was the increase of roughly 30 million feet in the production of Douglas fir. The cut of redwood rose about 5 million feet, and the production of white fir rose slightly. Other species showed decreases. The sampling error was 0.7 percent for redwood and 2.4 percent for Douglas fir. Lumber stocks decreased about 85 million feet. The 9 mills cutting more than 10 million feet apiece produced 88 percent of the regional cut, whereas the 38 mills cutting less than 1 million feet each produced 2.3 percent of the regional cut.

Table 1.- Production of lumber, by kind of wood, and of lath and shingles
California and Nevada 1/, 1941 and 1942

Species	Lumber production (M feet, b.m.)				Change in 1942 from 1941
	1941		1942 (estimate)		
	Quantity	Percent	Quantity	Percent	Percent
Mills sawing 50 M feet or more					
Ponderosa pine	1,177,513	50.5	1,133,565	48.8	- 3.7
Redwood 2/	455,449	19.5	460,631	19.8	+ 1.1
Sugar pine	299,378	12.8	261,661	11.3	- 12.6
Douglas fir	248,272	10.7	288,596	12.4	+ 16.2
White fir	100,965	4.3	131,331	5.7	+ 30.1
Incense cedar	36,737	1.6	35,791	1.5	- 2.7
Port Orford cedar	6,195	0.3	5,132	0.2	- 17.2
Sitka spruce	4,582	0.2	3,696	0.2	- 19.3
Alder	1,301	0.1	1,176	0.1	- 9.6
Other species 3/	598	0.0+	0	0.0	-100.0
Mills sawing less than 50 M feet					
All species	853	0.0+	591	0.0+	- 30.7
Total					
All species, all mills	2,331,893	100.0	2,322,170	100.0	- 0.4
Lath (thousands)	17,175		16,280		- 5.2
Shingles (squares) 4/	100,937		64,933		- 35.7
Stocks of lumber, Dec. 31	846,854		616,441		- 27.2

1/ Combined to avoid disclosing output of individual establishments.
2/ Includes big tree (*Sequoia gigantea*) in pine region.
3/ Hemlock, western red cedar, oak.
4/ Includes data for shakes reported as such.

Table [illegible].—Estimated production of lumber, by kind of wood and class of mill, and of lath and shingles
California Pine Region 1/, 1942

Class of mill	Active mills	Sampled mills	Lumber sawed (M feet, b.m.)								Sampling error[2] of estimated total production	Lumber on hand		Lath	Shingles
			Ponderosa pine	Sugar pine	Douglas fir	White fir	Incense cedar	Big tree	Total			Jan.1,1942	Dec.31,1942		
									Quantity	Percent					
	No.	No.									Percent	MBM	MBM	M pcs.	Squares
8 (50 MM and over)	7	7	514,747	104,288	24,517	30,696	13,451		687,699	39.8	0	188,590	138,492	6,455	0
7 (25 MM to 50 MM)	12	12	226,467	94,681	28,165	44,938	5,531		399,782	23.1	0	180,671	142,659	1,770	0
6 (15 MM to 25 MM)	13	13	150,822	26,511	51,557	27,430	5,222		261,542	15.1	0	110,921	92,170	0	0
5 (10 MM to 15 MM)	12	12	101,594	14,149	26,626	10,345	248		152,962	8.8	0	61,841	54,104	0	0
4 (5 MM to 10 MM)	10	10	35,817	11,124	5,044	9,114	7,428		68,527	4.0	0	14,531	10,004	0	0
3 (1 MM to 5 MM)	50	43	80,929	9,151	25,327	4,516	3,252	34	123,209	7.1	2.6	37,630	18,804	0	0
2 (500 M to 1 MM)	31	24	13,288	757	6,333	1,523	342	32	22,275	1.3	2.0	3,214	1,374	0	0
1 (50 M to 500 M)	77	63	9,174	996	2,451	1,321	317	171	14,430	0.8	3.7	1,875	1,051	0	293
0 (Under 50 M)	23	19	340	26	109	22	8		505	0.0+	5.4	31	36	0	169
Shingle	4	4									0			0	592
All classes	239[3]	207[3]	1,133,178	261,683	170,129	129,905	35,799	237	1,730,931	100.0	0.2	599,304	458,694	8,225	1,054
Sampling error[2] of estimated total production. (Percent)			0.3	0.4	1.7	0.6	2.4	20.2	0.2						

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[1] See footnote 1, table 3.
[2] Sampling errors are based on ± one standard error.
[3] Number of idle mills, estimated to be 84 (including one shingle mill), not included in totals.

wood Region 1/, 1942

.m.)		Total		Sampling error 2/ of estimated total production	Lumber on hand		Lath	Shingles
Sugar pine	Alder	Quantity	Percent		Jan.1,1942	Dec.31,1942		
				Percent	MBM	MBM	M pcs.	Squares
		373,491	63.2	0	185,766	123,605	5,403	24,702
		93,537	15.8	0	36,630	23,146	2,643	8,504
4		53,205	9.0	0	15,280	8,200	0	0
		28,504	4.8	0	3,142	1,741	0	439
		28,961	4.9	10.9	1,976	985	0	0
	820	8,571	1.5	3.0	134	26	0	1,222
	356	4,884	0.8	6.1	94	44	9	11,412
		86	0.0+	0	0	0	0	0
				35.4				17,600
4	1.176	591.239	100.0	0.5	243,022	157,747	8,055	63,879
4/	05/	0.5						

a, Napa, Marin, Santa Clara, San Mateo, Monterey, and Santa Cruz. Remainder of

ed in totals.
es 0-3 did not report cut of these species.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

Research Note No. 30 April 30, 1943

STUMPAGE AND LOG PRICES IN CALIFORNIA
BY SPECIES AND TYPE OF SALE
Preliminary Statistics for 1942

For several years the Forest Service, with the cooperation of the Bureau of the Census, has been collecting stumpage and log prices for use in studying the trend of values in the several timber producing regions. The information so obtained has been published on an annual basis, since 1929, in a series of statistical bulletins of the U. S. Department of Agriculture.

To comply promptly with requests for such information, the following tables of average 1942 stumpage and log prices for California have been prepared. They give average prices by species and type of sale as indicated by reports received to date from operating concerns and follow the statistical set-up in the printed bulletins. The data are preliminary and are subject to correction as additional reports may be received.

Additional copies of this release may be obtained upon request.

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STUMPAGE PRICES

State Totals

Species and type of sale	Trans-actions	Quantity	Total value	Average price per M	Price range per M
	Number	M ft.b.m.	Dollars	Dollars	Dollars
dividual softwoods					
Ponderosa pine	145	318,854	1,345,460	4.22	1.00 - 9.43
Sugar pine	51	95,233	470,135	4.94	1.75 - 9.43
Sitka spruce	2	1,024	1,390	1.36	.17 - 1.50
Western hemlock	5	1,245	498	.40	.17 - 2.50
Douglas fir	110	318,487	465,671	1.46	.17 - 3.90
White fir	44	53,596	48,458	.90	.25 - 3.90
Redwood	46	140,860	193,160	1.37	.53 - 4.50
Incense cedar	35	19,285	26,523	1.38	.50 - 3.50
Western red cedar	2	368	208	.57	.50 - 2.50
Port Orford cedar	4	658	1,874	2.85	1.50 - 7.00
Total, average, or spread	444	949,610	2,553,377	2.69	.17 - 9.43
Alder	1	820	2,460	3.00	--
at-rate softwoods	37	618,658	817,207	1.32	.15 - 5.00
ate total, average, or spread	482	1,569,088	3,373,044	2.15	.15 - 9.43

Pine Region

Species and type of sale	Trans-actions	Quantity	Total value	Average price per M	Price range per M
dividual softwoods					
Ponderosa pine	142	316,505	1,343,111	4.24	1.00 - 9.43
Sugar pine	51	95,233	470,135	4.94	1.75 - 9.43
Douglas fir	58	109,581	217,496	1.98	.25 - 3.90
White fir	41	35,416	39,272	1.11	.25 - 3.90
Redwood	3	93	419	4.50	--
Incense cedar	35	19,285	26,523	1.38	.50 - 3.50
Total, average, or spread	330	576,113	2,096,956	3.64	.25 - 9.43
at-rate softwoods	24	391,899	644,292	1.64	.50 - 5.00
gional total, average, or spread	354	968,012	2,741,248	2.83	.25 - 9.43

Stumpage Prices - (Continued)

Redwood Region

Species and type of sale	Trans-actions	Quantity	Total value	Average price per M	Price rang per M
	Number	M ft.b.m.	Dollars	Dollars	Dollars
Individual softwoods					
Ponderosa pine	3	2,349	2,349	1.00	--
Sitka spruce	2	1,024	1,390	1.36	.17 - 1.5
Western hemlock	5	1,245	498	.40	.17 - 2.5
Douglas fir	52	208,906	248,175	1.19	.17 - 3.0
White fir	3	18,180	9,186	.51	.50 - 2.5
Redwood	43	140,767	192,741	1.37	.53 - 4.5
Western red cedar	2	368	208	.57	.50 - 2.5
Port Orford cedar	4	658	1,874	2.85	1.50 - 7.0
Total, average, or spread	114	373,497	456,421	1.22	.17 - 7.0
Alder	1	820	2,460	3.00	--
Flat-rate softwoods	13	226,759	172,915	.76	.15 - 3.5
Regional total, average, or spread	128	601,076	631,796	1.05	.15 - 7.0

LOG PRICES

State Totals

Individual softwoods					
Ponderosa pine	39	41,043	613,117	14.94	9.00 -24.
Sugar pine	7	2,849	41,410	14.53	11.00 -16.
Sitka spruce	2	1,180	13,430	11.38	11.00 -14
Western hemlock	2	54	548	10.15	9.00 -10.
Douglas fir	39	22,923	257,147	11.22	8.60 -23.
White fir	13	2,176	20,747	9.53	8.50 -17.
Redwood	19	28,202	412,208	14.62	9.80 -35.
Incense cedar	5	115	1,113	9.68	9.25 -11.
Total, average, or spread	126	98,542	1,359,720	13.80	8.50 -35.
Alder	1	300	4,500	15.00	--
Flat-rate softwoods	5	5,434	86,459	15.91	10.00 -18.
State total, average, or spread	132	104,276	1,450,679	13.91	8.50 -35.

Log Prices – (Continued)

Pine Region

Species and type of sale	Transactions	Quantity	Total value	Average price per M	Price range per M
	Number	M ft.b.m.	Dollars	Dollars	Dollars
dividual softwoods					
Ponderosa pine	38	40,943	611,667	14.94	9.00 -24.00
Sugar pine	7	2,849	41,410	14.53	11.00 -16.00
Western hemlock	2	54	548	10.15	9.00 -10.50
Douglas fir	16	5,788	60,951	10.53	8.60 -23.00
White fir	12	2,128	20,332	9.55	8.50 -17.00
Redwood	1	25	338	13.52	--
Incense cedar	5	115	1,113	9.68	9.25 -11.24
Total, average, or spread	81	51,902	736,359	14.19	8.50 -24.00
at-rate softwoods	3	1,682	19,652	11.68	10.00 -11.94
gional total, average, or spread	84	53,584	756,011	14.11	8.50 -24.00

Redwood Region

Species and type of sale	Transactions	Quantity	Total value	Average price per M	Price range per M
dividual softwoods					
Ponderosa pine	1	100	1,450	14.50	--
Sitka spruce	2	1,180	13,430	11.38	11.00 -14.00
Douglas fir	23	17,135	196,196	11.45	9.00 -19.00
White fir	1	48	415	8.65	--
Redwood	18	28,177	411,870	14.62	9.80 -35.00
Total, average, or spread	45	46,640	623,361	13.37	8.65 -35.00
Alder	1	300	4,500	15.00	--
at-rate softwoods	2	3,752	66,807	17.81	16.91 -18.71
gional total, average, or spread	48	50,692	694,668	13.70	8.65 -35.00

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

Research Note No. 31 June 1, 1943

WATERING PLANTATION TREES[1]

by

R. H. Weidman
Institute of Forest Genetics

Low survival of forest planting stock has long been a serious obstacle to successful planting in regions of dry summer climate, such as the slopes of the Sierra Nevada in California, where the total rainfall for June, July, and August averages less than 3/4 of an inch. However, once established in this locality, planted trees make notably rapid growth. To assure survival of experimental trees the Institute of Forest Genetics has watered its plantations for the first few years after planting. This watering has resulted in 85 to 98 percent survival as compared with 5 to 20 percent survival in nearby farmers' plantations where no watering was done. These favorable results indicate that watering may be a practical measure for farm, park, windbreak, erosion control, camouflage, and other intensive plantings.

To determine minimum and adequate watering requirements, a pilot test was established, the 5-year results of which are now available. Two plots were planted on April 1, 1938, with 2-year-old ponderosa pine trees, 120 trees on each plot. One plot was on a moderately dry site at an altitude of 2,700 feet and the other was on a severely dry site at an altitude of 950 feet, which is close to the lower limit of natural ponderosa pine range in this locality. All the trees were watered at the time of planting. Thereafter one-fourth of the trees received no water whatever; one-fourth were watered once in midsummer; one-fourth received two summer waterings; and the remaining one-fourth received five summer waterings at intervals of 3 to 4 weeks beginning in early June. Seven gallons of water were applied per tree at each watering, the water being poured from buckets into basins formed with earth at the base of each tree. No plot was watered after the first summer.

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[1] This note is a digest of a longer article, Results of a Test of Watering Plantation Trees, by R. H. Weidman and C. R. Berriman, which is to be published in the near future.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Observation of the plots indicated that practically all the mortality of trees in the plots was due to drought. Table 1 shows that most of it occurred during the first year, little the second, and none thereafter. The results show further that there was no important difference in the survival of trees watered once and those watered twice, and that such infrequent waterings had but slight advantage over no watering whatever. Where five waterings were given, however, the survival was satisfactory for both plots and would doubtless have been higher at the dry Bassi location if the waterings had been better timed. The results show definitely that no watering need be done after the first year to insure survival.

Table 1.- Effect of different watering treatments on survival of ponderosa pine[1]

Location and altitude of plot	Year of survival count (taken each fall)	Treatment and survival Number of times watered during the first summer: None	One	Two	Five
	Year	Percent	Percent	Percent	Percent
Institute - altitude 2,700 feet	First	77	83	87	100
	Second[2]	-	-	-	-
	Third	70	80	77	97
	Fourth	70	80	77	97
	Fifth	70	80	77	97
Bassi[3] altitude 950 feet	First	33	40	43	83
	Second	23	30	33	83
	Third	23	30	33	83
	Fourth	23	30	33	83

[1] On the basis of 120 trees planted in each plot.
[2] No survival records were available for the second year.
[3] The Bassi plot was discontinued at the end of the fourth year.

Height measurements showed that the average growth of trees watered five times was appreciably greater than that of trees that received less water. The trees watered only once or twice showed little difference in height as compared with each other or with those not watered at all.

Another feature of the experiment was the mulching of half of the trees with pine litter in an effort to conserve moisture. For the trees watered once or twice, this treatment increased survival 13 to 20 percent as compared with no mulching. Where intensive watering was done the survival was high regardless of mulching.

Whether plantation trees need watering to assure high survival depends chiefly on the distribution and amount of rainfall during the first growing season. Another important factor is water-holding capacity of the soil. With these points in mind the quantity and intervals to be used in artificial watering depend on seasonal need. By digging holes from time to time during the summer to the depth at which absorbing root tips are located, it is possible to judge approximately by the color and feel of the soil the time to apply water.

It is not intended, of course, from this limited pilot test to suggest the watering or irrigation of extensive State or national-forest plantations. There are forest plantings of a more intensive nature, however, in connection with farm forestry, windbreaks, erosion control, municipal watersheds, and similar projects, where watering the first year would be possible and profitable.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

Research Note No. 32 May 10, 1943

TAPER AND VOLUME TABLES FOR PONDEROSA PINE ON SITE IV-100 IN CALIFORNIA

By

R. F. Keniston, Junior Forester

and

V. A. Clements, Associate Silviculturist

Satisfactory taper and volume tables for ponderosa pine on Site IV-100[1] in California have long been needed. Extensive areas of valuable old-growth timber occur in this site class in the "Eastside" pine type, especially on the Modoc Plateau in the northeastern part of the State. Expansion of lumbering in these forests has increased the demand for tables to be used in cruising, appraisals, and working plans.

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[1] Site IV-100 is the designation used for sites on which the dominant trees average 100 feet in height at 300 years. The site scale is described in Research Note No. 28, Calif. Forest & Range Expt. Sta., "A Site Classification for the Mixed-Conifer Selection Forests of the Sierra Nevada," by Duncan Dunning, 1943.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

When volume tables for the first three site classes were completed in 1922, no tree measurements were available for Site IV-100. Field measurements for this site were made in 1924, but the data proved to be unsuitable. A table made in 1925 from measurements of 127 trees in the Modoc National Forest apparently fits the timber fairly well, but was intended as a local table and has not been tested for wider application. In 1927 a range-wide series of volume tables was constructed in the Washington office of the Forest Service, and the Site IV table[2] of this series has been used in timber surveys in Region 5. The site scale to which this table is related differs from that of Region 5. The trees on which it is based included none from California; all represented the Rocky Mountain form of ponderosa pine. The check of tabular values against scaled volumes, discussed later in this note, indicates that this table is not well adapted to the Modoc timber. Careful tests of its suitability for other localities in California have not been made.

Taper tables yielding values corresponding to those in the volume table have not been available heretofore. Log grading and other refinements in appraisals have emphasized the importance of taper tables and the desirability of having corresponding volume tables derived from the taper measurements.

In response to these requirements the 127 Modoc trees of 1925 have been combined with 121 trees from the same locality measured in 1925 and 1930 to produce the volume and taper tables presented here.

The taper tables were constructed and harmonized graphically. The volume table was prepared directly from the taper tables by summarizing the log volumes for trees of various diameters and heights.

The taper tables give the diameter and volume of the top log as scaled at the uppermost 16-foot interval falling nearest to 8 inches inside bark. This was done for convenience of interpolation in preference to the usual procedure of scaling the top logs uniformly to a diameter of 8 inches but with variable length. It should be emphasized that correct use of these tables requires classification of the trees in the usual manner, that is, by height in 16-foot logs to an 8-inch top.

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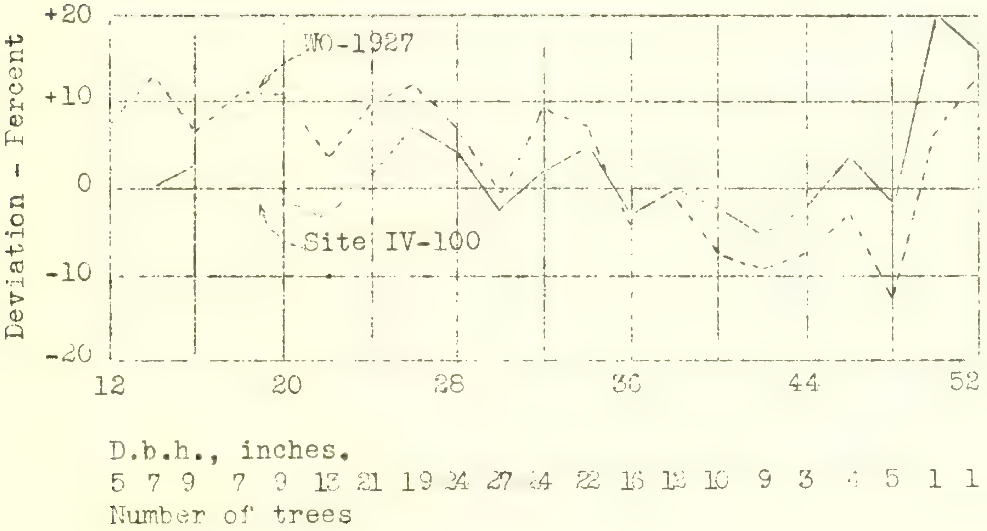
[2] Evans, O. M. 1938. Multiple volume tables. Form 71, R-5, sheets 1 to 44. U. S. Forest Service, San Francisco.

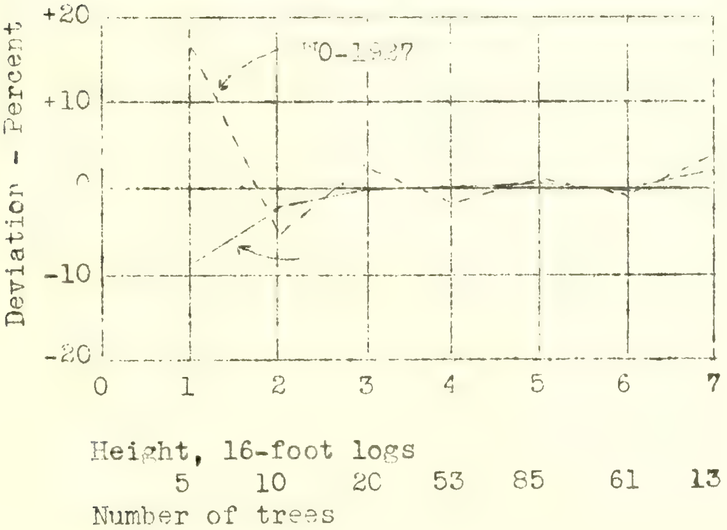
It is hoped that these tables may prove satisfactory as standards for the territory. They should not be accepted as such, however, until dependable checks have been made under conditions of field use. Unfortunately such tests often are neglected or, because of defective procedure, are inconclusive. By the time shortcomings are finally exposed, many related tables such as cubic foot, board foot by International Rule, tables based on total height and similar variations have got into use and must be abandoned with the originals. As a guide to field testing, essential information on methods of construction is printed on the tables.

In 1927 range-wide Site IV table gave a total volume for the 248 Modoc trees only 840 bd. ft. greater than the scale but, as indicated by the accompanying graph, this close agreement resulted from compensating departures: the older table gave values consistently too high for the smaller trees and too low for the larger ones.

Comparison of the new Site IV-100 tabular volume with the total scaled volume of the 248 basic trees shows a difference of no consequence -- the table giving only 890 bd. ft., or 0.26 percent more than the direct scale of 338,870 bd. ft. The graph shows that the tabular deviations from scale for the several diameter and log classes also are consistently small and that the departures show no undesirable trend with either diameter or height. It is hoped that future tests will confirm the indicated superior fit of the new table.

Comparison of new Site IV-100 and Washington Office-1927 volume tables: Diameter and height class deviations from the scale of 248 trees in percent.





TAPER AND VOLUME TABLES
PONDEROSA PINE
(*Pinus ponderosa*)
Site IV-100

U. S. Forest Service Region 5
Prepared by
California Forest and Range Experiment Station
1943

Keniston
Clements

Scribner Dec.
Logs 16.3 ft.
Top d.i.b. 8 i
Stump 1.5 ft.

D.b.h. inches	Height: 16' logs to 8" top	Log number								Log number								Tr vol bd. ft.
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
		Diameter inside bark - inches								Volume - board feet - tens								to
12	1	8								3								
	2	9	7							4	3							
14	1	9								4								
	2	10	8							6	3							
	3	10	9	7						6	4	3						[illegible]
16	1	10								6								
	2	11	8							7	3							[illegible]
	3	12	10	7						8	6	3						[illegible]
	4	12	11	9	6					8	7	4	2					[illegible]
	5	12	11	10	9	6				8	7	6	4	2				
18	1	11								7								
	2	12	9							8	4							[illegible]
	3	13	11	8						10	7	3						
	4	14	12	10	7					11	8	6	3					[illegible]
	5	14	13	12	10	6				11	10	8	6	2				[illegible]
	6	15	14	13	11	9	6			14	11	10	7	4	2			[illegible]
20	1	13								10								1
	2	14	10							11	6							1
	3	15	12	9						14	8	4						2
	4	15	13	11	7					14	10	7	3					3
	5	15	14	13	10	6				14	11	10	6	2				4
	6	17	15	14	13	10	6			18	14	11	10	6	2			6
	7	17	16	15	14	13	9	4		18	16	14	11	10	4	1		7
22	2	15	11							14	7							2
	3	16	13	9						16	10	4						3
	4	17	15	12	8					18	14	8	3					4
	5	17	16	14	11	7				18	16	11	7	3				5
	6	18	17	16	14	11	6			21	18	16	11	7	2			7
	7	19	18	17	15	14	10	4		24	21	18	14	11	6	1		9

D.b.h.	Height: 16'logs	Log number								Log number								Tree volum
inches	to 8" top	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	bd. f
		Diameter inside bark - inches								Volume - board feet - tens								tens
24	2	16	12							16	8							24
	3	18	15	10						21	14	6						41
	4	19	16	13	8					24	16	10	3					53
	5	19	17	15	12	7				24	18	14	8	3				67
	6	20	18	17	15	11	6			28	21	18	14	7	2			90
	7	20	19	18	17	15	11	5		28	24	21	18	14	7	1		113
26	2	17	13							18	10							28
	3	19	16	10						24	16	6						46
	4	20	18	14	9					28	21	11	4					64
	5	21	19	16	13	8				30	24	16	10	3				83
	6	22	20	18	16	12	7			33	28	21	16	8	3			109
	7	22	21	20	18	16	12	5		33	30	28	21	16	8	1		137
28	2	18	13							21	10							31
	3	20	17	11						28	18	7						53
	4	22	19	16	9					33	24	16	4					77
	5	23	21	18	14	8				38	30	21	11	3				103
	6	23	21	19	17	13	7			38	30	24	18	10	3			123
	7	24	23	21	19	17	12	5		40	38	30	24	18	8	1		159
30	3	22	18	12						33	21	8						62
	4	24	21	17	10					40	30	18	6					94
	5	24	22	19	15	9				40	33	24	14	4				115
	6	25	23	21	18	14	7			46	38	30	21	11	3			149
	7	26	24	23	21	18	13	6		50	40	38	30	21	10	2		191
32	3	24	19	12						40	24	8						72
	4	25	23	18	10					46	38	21	6					111
	5	26	24	20	16	9				50	40	28	16	4				138
	6	26	25	22	19	14	7			50	46	33	24	11	3			167
	7	28	26	24	22	19	14	6		58	50	40	33	24	11	2		218
34	3	25	21	13						46	30	10						86
	4	27	24	19	11					55	40	24	7					126
	5	28	25	22	17	9				58	46	33	18	4				159
	6	28	26	23	20	15	8			58	50	38	28	14	3			191
	7	29	28	26	23	20	14	6		61	58	50	33	28	11	2		248
36	3	27	22	14						55	33	11						99
	4	29	26	21	11					61	50	30	7					148
	5	30	27	23	17	10				66	55	38	18	6				183
	6	30	28	25	22	16	8			66	58	46	33	16	3			222
	7	31	29	27	24	20	15	7		71	61	55	40	28	14	3		272

D.b.h. inches	Height: 16'logs to 8" top	Log number								Log number								Tree volume bd. ft. tons
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
		Diameter inside bark - inches								Volume - board feet - tons								
38	3	28	23	14						58	38	11						107
	4	31	28	22	12					71	58	33	8					170
	5	32	28	24	18	10				74	58	40	21	6				199
	6	32	30	26	23	16	8			74	66	50	38	16	3			247
	7	33	31	29	26	21	16	7		78	71	61	50	30	16	3		309
40	4	33	30	23	12					78	66	38	8					190
	5	34	30	26	19	11				80	66	50	24	7				227
	6	34	32	28	24	17	8			80	74	58	40	18	3			273
	7	35	33	30	27	22	16	7		88	78	66	55	33	16	3		339
42	4	35	31	25	13					88	71	46	10					215
	5	35	32	27	20	11				88	74	55	28	7				252
	6	36	34	30	25	18	9			92	80	66	46	21	4			309
	7	37	35	32	28	23	17	8		103	88	74	58	38	18	3		382
	8	37	35	33	31	27	22	16	7	103	88	78	71	55	33	16	3	447
44	4	37	33	26	13					103	78	50	10					241
	5	37	34	29	21	12				103	80	61	30	8				282
	6	38	35	31	26	19	9			107	88	71	50	24	4			344
	7	38	36	33	29	24	17	8		107	92	78	61	40	18	3		399
	8	39	37	35	32	28	23	16	7	112	103	88	74	58	38	16	3	492
46	4	39	35	27	14					112	88	55	11					266
	5	39	35	30	22	12				112	88	66	33	8				307
	6	40	37	33	28	20	9			120	103	78	58	28	4			391
	7	40	38	34	30	24	18	8		120	107	80	66	40	21	3		437
	8	40	39	36	32	28	23	16	8	120	112	92	74	58	38	16	3	513
48	4	41	37	29	14					127	103	61	11					302
	5	41	37	31	22	12				127	103	71	33	8				342
	6	42	39	35	29	21	10			134	112	88	61	30	6			431
	7	42	39	36	31	25	18	9		134	112	92	71	46	21	4		480
	8	42	40	37	33	29	23	16	8	134	120	103	78	61	38	16	3	553
50	5	43	39	33	23	13				140	112	78	38	10				378
	6	44	41	36	30	21	10			148	127	92	66	30	6			469
	7	44	41	37	32	26	18	9		148	127	103	74	50	21	4		527
	8	44	42	38	34	29	24	16	8	148	134	107	80	61	40	16	3	589
52	5	45	41	34	24	13				152	127	80	40	10				409
	6	45	42	38	32	22	10			152	134	107	74	33	6			506
	7	46	42	38	33	26	19	9		159	134	107	78	50	24	4		556
	8	46	43	39	35	30	24	16	8	159	140	112	88	66	40	16	3	624

D.b.h. inches	Height 16' logs to 8" top	Log number 1	2	3	4	5	6	7	8	Log number 1	2	3	4	5	6	7	8	Tree volume bd. f
		Diameter inside bark - inches								Volume - board feet - tens								tens
54	5	47	43	36	25	14				166	140	92	46	11				455
	6	47	44	40	33	23	10			166	148	120	78	38	6			556
	7	47	44	40	34	27	19	10		166	148	120	80	55	24	6		599
	8	48	45	41	36	30	24	16	9	173	152	127	92	66	40	4		670
56	5	49	44	37	26	14				180	148	103	50	11				492
	6	49	46	41	34	24	11			180	159	127	80	40	7			593
	7	49	46	41	35	28	19	10		180	159	127	88	58	24	6		642
	8	50	47	42	36	30	24	16	9	187	166	134	92	66	40	16	4	705
58	6	51	47	43	36	25	11			195	166	140	92	46	7			646
	7	51	47	43	36	28	20	10		195	166	140	92	58	28	6		685
	8	52	48	43	37	31	24	16	9	202	173	140	103	71	40	16	4	749
60	6	53	49	44	37	27	11			210	180	148	103	50	7			698
	7	53	49	44	37	29	20	11		210	180	148	103	61	28	7		737
	8	54	50	44	38	31	24	16	9	218	187	148	107	71	40	16	4	

Basis 248 trees, Modoc National Forest, 1923, 1924, 1925, and 1930.

VOLUME TABLE
PONDEROSA PINE
(Pinus ponderosa)
Site IV-100
U. S. Forest Service Region 5
Prepared by
California Forest and Range Experiment Station
1943

Mariston
Clements

Scribner, Decimal C.

Volume, bd.ft. - tens

D.b.h. inches	Number of 16-foot logs to 8.0" top d.i.b. 1	2	3	4	5	6	7	8	No. of trees
12	3	7	..	..	..	..	..	..	5
14	4	9	13	..	..	..	..	..	7
16	6	10	17	21	27	..	..	..	9
18	7	13	20	28	37	48	..	..	7
20	10	17	26	34	43	61	74	..	9
22	..	21	30	43	55	75	95	..	13
24	..	24	41	53	67	90	113	..	21
26	..	29	46	64	83	109	137	..	19
28	..	31	53	77	103	123	159	..	24
30	..	..	62	94	115	149	191	..	27
32	..	..	73	111	138	167	218	..	24
34	..	..	86	126	159	191	248	..	22
36	..	..	96	148	183	222	272	..	16
38	..	..	107	170	199	247	309	..	12
40	..	..	..	190	237	273	339	..	10
42	..	..	..	215	252	309	382	447	9
44	..	..	..	241	282	344	390	492	3
46	..	..	..	266	307	391	437	513	4
48	..	..	..	303	342	431	486	553	5
50	..	..	..	..	378	469	537	589	1
52	..	..	..	..	409	506	556	634	1
54	..	..	..	..	455	556	599	670	..
56	..	..	..	..	492	597	642	705	..
58	..	..	..	..	..	646	685	749	..
60	..	..	..	..	..	698	737	791	..
No. of trees	6	10	20	53	85	61	13	..	248

Prepared from taper table for Site IV-100.
Basis: 248 trees measured on the Modoc National Forest in 1923, 1924, 1925, and 1930.
Stump height 1.5 feet.
Scaled in 16.3 ft. logs to full log nearest 8.0 inch top d.i.b.
Aggregate deviation: table 0.26% high.
Average percentage deviation: 12.4%

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director

Research Note No. 34 June 21, 1943

BITTERBRUSH IN CALIFORNIA[1]

By August L. Hormay

Associate Forest Ecologist

INTRODUCTION

Bitterbrush (Purshia tridentata D. C.) is one of the most important range plants in the West. It is grazed by cattle, sheep, and goats, as well as by deer, antelope, and other game animals, and the seeds are an important item in the diet of rodents and birds.

The range of bitterbrush (fig. 1) covers about 340,000,000 acres in the 11 western range States and southern British Columbia. In California bitterbrush is distributed on approximately 7,500,000 acres east of the Sierra Nevada and Cascade Mountains at altitudes ranging from 3,500 to 11,000 feet. It commonly grows on sites occupied by big sagebrush (Artemisia tridentata), ponderosa and Jeffrey pine (Pinus ponderosa and P. Jeffreyi), Sierra juniper (Juniper occidentalis), and singleleaf pinon (Pinus monophylla). Bitterbrush grows best on soils that are well-drained, moderately deep, and fine- or coarse-textured. In many places it forms most of the ground cover. It is rather intolerant of shade, and the densest stands are found in forest openings and clearings and on slopes below the pine forest.

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[1] This study was furthered in many ways by the cooperation and actual participation of Region 5 personnel, more particularly, F. P. Cronemiller, F. D. Douthitt, and A. Fausett of the Division of Wildlife and Range Management, Regional Office; and numerous staff men of the eastside national forests (Shasta, Modoc, Lassen, Plumas, Tahoe, Mono, and Inyo) in analyzing bitterbrush problems in the field and in gathering data on the distribution and artificial reseeding of the plant. Comments on the manuscript by the U. S. Fish and Wildlife Service; the Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine; the Department of Botany, University of California; the Forest Service, Washington, and this Station were very helpful in the preparation of this paper.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

On large areas this valuable range browse has been destroyed or damaged by fire, too heavy and untimely grazing by livestock and game animals, defoliation by caterpillars, or girdling by rodents. Drought, unfavorable temperatures, and other factors of weather have in many cases made the plant more susceptible to injury. In many localities not enough reproduction is becoming established to perpetuate the stands. Over a period of years a serious decrease in range production has resulted from such damage to bitterbrush. Much critical observation was made of bitterbrush in California in past years, and the experiments here reported were begun in 1940. The object of these studies was to obtain additional facts, principally on the growth and reproduction of the species, that would be helpful in the management and rehabilitation of this browse on the ranges. The following report applies to California but some of the findings may also hold in other regions.

DESCRIPTION

Bitterbrush is a diffusely branched, deciduous shrub (fig. 2) of the rose family (Rosaceae). It is usually 2 to 6 feet tall but in some places it attains a height of 16 feet and a stem diameter of 12 inches. The leaves are 1/4 to 3/4 inch long, three-toothed on the ends, and are grouped in small bunches on the twigs and stems. The plants range in color from dark green to light gray. Different-colored plants often grow side by side. The leaves of the light-colored ones are densely covered with white matted hairs, whereas those of dark plants are almost smooth and often much smaller. On some dark plants the leaves are sticky and have a strong obnoxious resinous scent because of the presence of glandular hairs and pustule-like glands. The plant bears numerous five-petalled flowers about 3/4 inch in diameter, which grade in color from pale cream to bright yellow on different plants. The stamens, of which there are about 25, and the petals are attached to the rim of a cuplike receptacle which contains the ovary.

The plant is called quininebrush, deerbrush, buckbrush, antelopebrush, greasewood, and black sage as well as bitterbrush. In sagebrush types it stands out as a dark-colored plant. The names bitterbrush and quininebrush are appropriate because all parts of the plant, even the flowers and the wood, have a very bitter taste. The bitter substance was isolated in two pharmacological studies, but its chemical composition was not determined. It was reduced to crystalline form and was found soluble in water. It is not an alkaloid nor a glucoside. The plant was also found to contain appreciable quantities of tannin.

The young seedling (fig. 3) has cotyledons which are lobed at the base and are 3/8 to 1/2 inch long and 1/4 to 3/8 inch wide. The young stem below the cotyledons is conspicuously red. This character is an aid to recognizing the seedlings in the field. The edges of the cotyledons, the upper portion of the young stem, and the young leaves are dotted with red glandular hairs.

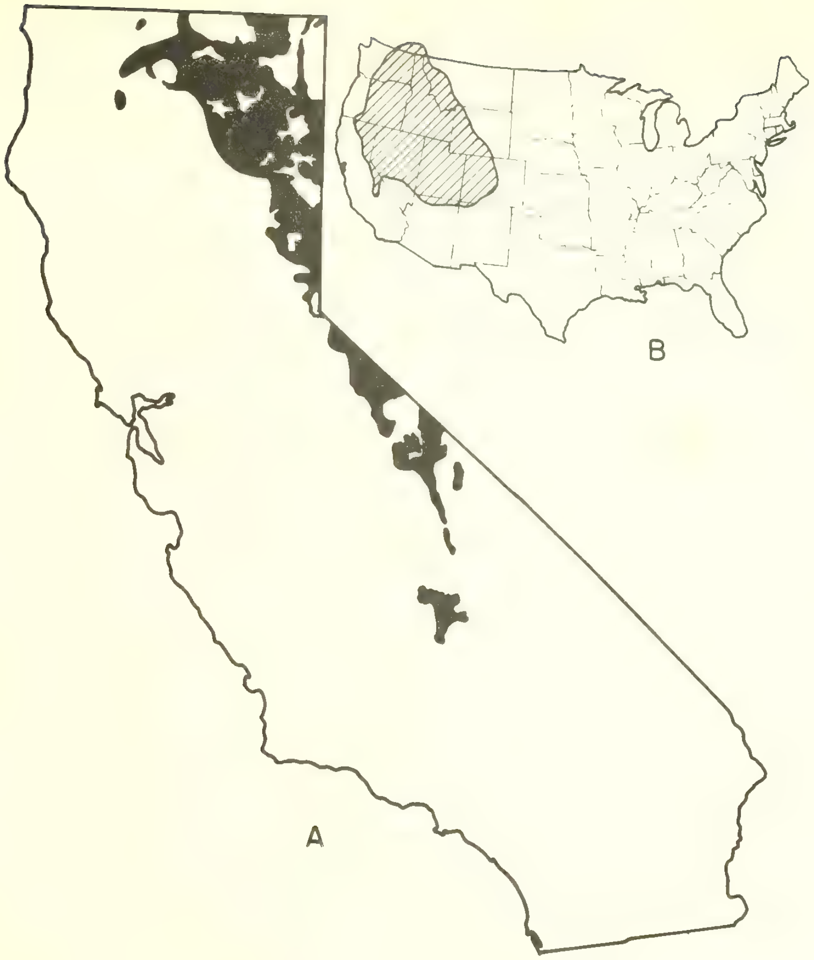


Fig. 1. General distribution of bitterbrush: A, In California; and B, in the United States and southern British Columbia. Based on information from the U. S. Forest Service, Region 5, and the Division of Dendrology and Forage Investigations, Forest Service, Washington, D. C.

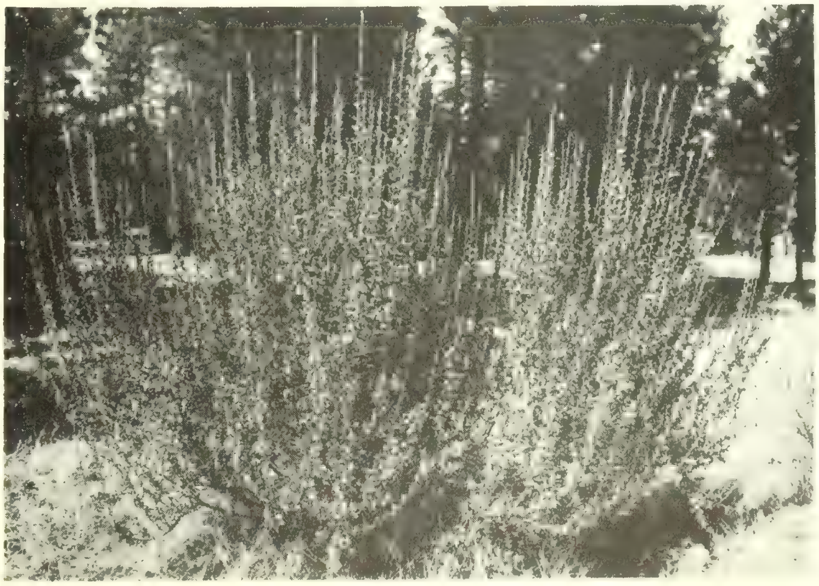


Fig. 2. Characteristic form of ungrazed bitterbrush.

The seeds of bitterbrush resemble apple seeds in size and shape. They are egg-shaped, slightly flattened, and about 1/4 to 3/8 inch long. When wet they are dark reddish purple to almost black in color, but when dry they are grayish and tinged with purple and brown. The coat of the maturing seed contains a reddish purple sap which congeals into a hard granular mass when the seed is fully ripe. Each seed is enclosed in a spindle-shaped, ribbed husk about 3/8 to 5/8 inch long. Together the husk and seed constitute the fruit — a dry achene.

FORAGE VALUE

Bitterbrush is the most important range browse east of the Sierra Nevada-Cascade Divide in California. It forms only a small part of the forage crop in some localities but in others it constitutes the bulk of the livestock feed. Some stands exceed 0.5 density. A stand of 0.2 density with twig growth averaging 7.5 inches long will yield about 900 pounds of dry forage per acre.

Experiments at the University of Nevada in 1909 showed that crude protein makes up about 13 percent of the dry weight of the young leaves and twigs. In feeding tests with sheep 82 percent of this protein was found to be digestible. These tests further showed that in 100 pounds of dry matter 9.72 pounds of protein, 62.50 pounds of carbohydrate, and 2.25 pounds of fat were digested. Experiments in 1942 at the Utah Agricultural Experiment Station showed 15 percent protein in the leaves and tender twigs in June and 10 percent in September. The high protein content of bitterbrush even in September indicates its value in offsetting protein deficiencies that develop on many western ranges after the herbaceous vegetation dries up. Bitterbrush is especially valuable on the range because it provides green forage 4 to 6 weeks longer in the fall than most of the bunchgrasses and herbs on the same site. Thus it adds to the length of the grazing season.

GROWTH AND REPRODUCTION

The seasonal growth of the mature bitterbrush plant is illustrated in table 1. It should be noticed that twig growth starts after flowering. The season's flowers and seeds are borne on short spurs from previous years' wood and not on the current shoots. The new shoots produce seeds the following season if protected from excessive grazing and if other conditions permit. Twig growth continues into the early part of September, providing succulent green forage late in the season. It has been observed that grazed bushes remain green longer than un grazed ones, probably because grazing stimulates regrowth and because less water is lost from the grazed plant through transpiration.

TABLE 1. Seasonal growth and development of bitterbrush, Halls Flat, Lassen National Forest, 1942

Stage	Month							Development period
	May	June	July	Aug.	Sept.	Oct.	Nov.	
Leaves growing	xx							May 8 - 20
Plants flowering		xxx						June 1 - 20
Twigs growing		xxxx	xxxxx	xxxxx	xx			June 10-Sept. 6
Seeds ripe and falling				xx				Aug. 1 - 10
Leaves falling					xxxx	xxxxx	xxxxx	Sept.-Nov.

The seedlings emerge from the ground in the spring at about the time the parent plants start to grow. They rarely get to be more than 2 or 3 inches tall by the end of the first season. Their roots, however, penetrate the soil to depths of 15 to 20 inches or more. Flowering of ungrazed plants starts in the fourth or fifth year on some sites and 2 or 3 years later on others. At this stage the plants have a spread of about 8 to 10 inches and are 10 to 12 inches high. Seed production usually does not occur in appreciable quantities until the plants are 10 years old or older and have attained considerable size.

A comparison of the number of annual rings with the known age of plants indicates that the stems of bitterbrush form one growth ring a year. If rings have not been destroyed the age of dominant plants can be determined within 2 or 3 years by counting the rings in a section through the main stem at the ground line. The oldest stem examined by the writer had 82 rings. The life span of bitterbrush is probably between 60 and 70 years.

Bitterbrush reproduces mainly from seed. Occasionally, after injury of the crown by fire, chopping, or crushing, it sprouts from some of the numerous adventitious buds located near the base of the main stems, but this is not an important means of propagation of the plant. Only two instances of sprouting after burning have been observed in California, one near Delleker on the Plumas National Forest and one near Big Pine on the Inyo National Forest.

Factors Influencing Growth and Reproduction

Rodents.--Widespread observations and measurements by the writer indicate that most of the plants in bitterbrush stands become established from seeds cached by rodents. Upon germination the seeds produce a thick cluster of seedlings which form a single crown (fig. 4, A and B). The size and shape of this crown resembles that of a single older bitterbrush plant. This similarity may have led to the widely prevalent but erroneous idea that practically no seedlings were present in some localities.

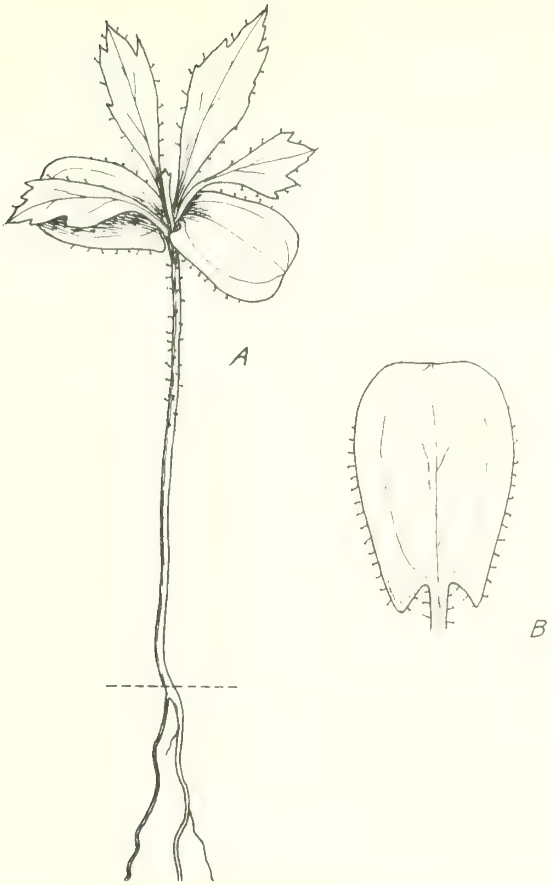
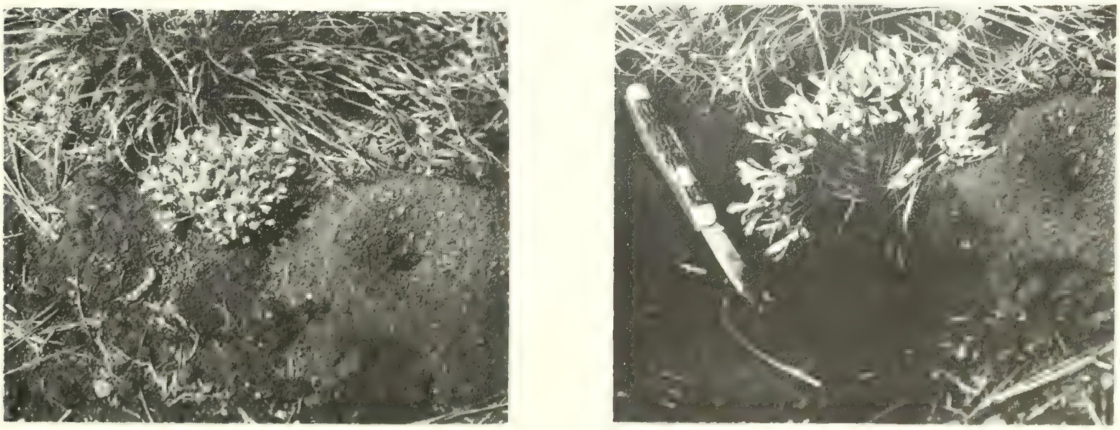


Fig. 3. A, Bitterbrush seedling, 1 month old; B, cotyledon of seedling.



A

B

Fig. 4. A, A cluster of bitterbrush seedlings germinating from a rodent seed cache; B, the seedlings shown in A partly excavated and spread out to show numbers.

In a stand on the Lassen National Forest 58 percent of all the bitterbrush crowns were made up of two or more plants (table 2). No doubt many of the single plants in the stand were also part of rodent caches originally, since many caches are reduced to one surviving plant. The bitterbrush stand shown in table 2 has a uniform distribution of sizes, indicating that reproduction has become established at relatively frequent intervals.

TABLE 2. Number of plants per crown in a lightly grazed bitterbrush stand, Crater Mountain, Lassen National Forest, 1941

Plants per crown	Number of crowns[1] by approximate diameter of stems of plants -- inches									Total	Percent
	1/16	1/8	1/4	1/2	1	1½	2	2½	3		
1	13	8	3	7	12		6		3	52	42
2	1	3	4	6	9		2		2	27	22
3			5	2	2		2			11	9
4		1	2	3	4					10	8
5		1		2	4					7	6
6	1	2	2		2					7	6
7				1	1					2	1
8	1	1								2	1
9			1							1	1
10	1				2					3	2
11	1									1	1
17		1								1	1
Total	18	17	17	21	36		10		5	124	
Percent	14	14	14	17	29		8		4		100

[1] In a sample plot 3.3 ft. by 330 ft.

The caches are found buried from 1/4 to 1-1/2 inches below the surface of the soil and contain seeds, not fruits. Not all of the seeds in a cache germinate; the number germinating varies from 2 to over 100. In one cache 139 seedlings were found. Most of the caches are located in the spaces between shrubs where light is favorable for the establishment and survival of the seedlings. Seedlings under or around the edges of the crowns of older plants do not survive. It is rare to find a plant with a stem as large as 1/2 inch in diameter growing under an older plant.

The caching of bitterbrush seeds by rodents has not been actually observed, but it is suspected that chipmunks and golden-mantled ground squirrels do most of the caching. These rodents have been seen digging into the base of germinating seedlings in the spring in search of ungerminated seed. Mice also probably cache many of the seeds, but other seed-caching rodents are too scarce to account for much of the planting that occurs. A representative of the Fish and Wildlife Service concurred in these initial observations after a brief field check.

Chipmunks eat large quantities of the ripening seed. The sticky red juice of the seed coat, which remarkably resembles blood, gets on their feet and can be found smeared on rocks, sticks, logs, stumps, fence posts, stems of shrubs, and even on tree branches 5 or 6 feet above the ground. The amount of red juice on these objects roughly indicates the degree of rodent activity and the amount of bitterbrush seed produced during the season in a given area. Evidence of rodents' eating bitterbrush seeds is found almost everywhere during summer and fall. The remains of fruits and seed coats may be seen on rocks, logs, and stumps. Only the embryos of the seeds are eaten.

As seed-caching sites, rodents prefer soft, loose, or recently disturbed soils such as road shoulders, road banks, borrow pits, and areas disturbed by logging. The deep duff and litter at the base of pine trees is a favored planting site. Seedlings may be found there when they cannot be located elsewhere in the vicinity.

The amount of caching varies from year to year depending primarily on the amount of seed produced. In 1941 large numbers of caches were found on experimental plots. In 1942 there were very few. In 1943 germinating seed caches could be found by the thousands throughout the eastside region in lightly grazed stands. It is interesting that practically no caches were found in several dense stands of very large plants — 6 to 12 feet tall — on the Shasta, Lassen, and Mono National Forests, in spite of heavy seed production.

Rodents are detrimental as well as beneficial to bitterbrush. Plants have been observed to be killed by girdling of the stems during the winter, probably by mice. This cause of mortality is reported to be prevalent in parts of Oregon, Idaho, and Nevada, and further observation may reveal it to be more widespread in California than it now appears. It is doubtful however, if bitterbrush could perpetuate itself on California ranges without rodents in the face of the many factors that act to destroy the stands.

Destruction of seed-caching rodents would be detrimental to the propagation not only of bitterbrush but perhaps of other important forage species. Seeds of Idaho fescue (*Festuca idahoensis*), squirreltail (*Sitanion hystrix*), needlegrass (*Stipa occidentalis*), downy chess (*Bromus tectorum*), squaw mat (*Ceanothus prostratus*), snowberry (*Symphoricarpos* sp.), greenleaf manzanita (*Arctostaphylos patula*), Jeffrey pine, and unidentified species of forbs have been found in rodent caches. No doubt rodents cache the seed of many other important range and forest species. In 1943 a large part of the Jeffrey pine reproduction observed in the eastside region germinated in rodent caches. Several species often grow in the same cache. Bitterbrush and Jeffrey pine seedlings frequently occur together. Seedlings in rodent caches are conspicuous in the spring on burned areas and on dirt roads that were graded in the fall.

Livestock grazing.—Continuous heavy grazing by livestock season after season is probably the main cause of the widespread deterioration of bitterbrush on ranges. Heavy grazing is harmful primarily because it removes most of the twigs that bear the flowers and seeds and tends to kill the established seedlings and older plants in the stand.

If heavy grazing starts when the plant is young and persists for several years, bitterbrush acquires a prostrate mushroomlike shape (fig. 5). If heavy grazing starts when the plants are well grown, they become rounded back, lobed, or club-shaped, but they remain taller than the prostrate form. These cropped-back plants often live for a long time because the dense woody twig stubble left from previous years protects about 15 to 20 percent of the foliage from grazing.

Club-shaped and mushroom-shaped plants usually occur on heavily grazed ranges or where the stands are thin and the plants widely scattered. They are more prevalent on heavily grazed cattle ranges than on heavily grazed sheep or deer ranges because cattle eat not only the current twig growth but also woody branches as large as one-fourth of an inch in diameter. They tend to graze the plants more heavily on the top than sheep or deer graze them, and the plants are often kept down to a height of 1 or 2 feet. Sheep and deer, on the other hand, confine their grazing mainly to the current year's growth, frequently stripping off only the leaves and rarely utilizing the woody growth of previous years. A few shoots usually remain ungrazed and eventually some of the branches grow even beyond reach of the animals. These plants maintain an open straggly form (fig. 6). Apparently they do not maintain their vigor under heavy grazing as well as cropped-back plants because most of the foliage is removed, but they do ripen some seeds.

The palatability of this browse varies in different plants and with stage of growth, degree of use, and site location. Many stockmen and range technicians say that previously ungrazed bitterbrush is only lightly grazed by cattle or sheep. They believe that the plant has to be grazed at least moderately each year to remain palatable to livestock. Sharp dead twigs on the plant are known to hinder sheep grazing. A clearer understanding of the causes of variations in palatability of bitterbrush is necessary for the efficient management of the plant.

From present observations it is estimated that about 40 percent of the twig growth should remain on the bitterbrush plant each season to maintain plant vigor and to insure adequate seed production. Where bitterbrush makes up 25 percent or more of the forage and is heavily grazed, a reduction in livestock numbers will probably increase its vigor and reproduction. However, where bitterbrush makes up only a small part of the forage, even light grazing of the range as a whole will result in close use of the plant because of its high palatability. On these ranges, as well as where the shrub is more abundant, a system of deferred and rotation grazing that protects a portion of the range from use for an entire season every 4 or 5 years would probably provide the necessary twigs for maintaining high plant vigor and an abundant seed supply.

Deer grazing.--In certain localities winter use of bitterbrush by mule deer is heavy and summer use is light to moderate. Columbian black tailed deer and antelope also graze bitterbrush but primarily in spring and summer.

Bitterbrush stands grazed by mule deer in winter and by livestock in summer show marked signs of deterioration. The winter use by deer is sometimes greater than the summer use by livestock. Satisfactory management of bitterbrush depends in part on knowing the relative effect of these different seasons of use on vigor and reproduction of the plant. Bitterbrush occurring in sparse stands may be grazed sufficiently by deer alone to prevent adequate seed production.

Defoliation by caterpillars.-- Defoliation of bitterbrush by the Great Basin tent caterpillar frequently kills the plant or greatly reduces its vigor. The Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine, Berkeley, has studied the tent caterpillar for several years and found that infestations occur over large areas throughout the range of bitterbrush and vary in severity from one year to the next and from one locality to another.

Epidemics are usually controlled within 2 or 3 years by natural causes such as the increase of insect enemies. The tent caterpillar can be killed in both egg and caterpillar stages by the use of insecticides, including light penetrating oils, that are nonpoisonous to livestock and the plant. However it is not economically feasible or practical to treat extensive range areas by these means to effect control of the insect.

The writer has observed that plants weakened by grazing or by previous caterpillar infestations may be seriously damaged or killed by a single heavy defoliation. Plants not weakened by such causes will often recover quickly after a heavy attack by caterpillars. Removal of 50 percent or more of the leaves by caterpillars reduces or prevents flower production the following season, even in vigorous plants. This suggests that grazing by livestock of more than half the foliage during the season will impair seed production.

Burning.-- Hundreds of thousands of acres of bitterbrush have been destroyed by fire. Fire is especially harmful because it kills the plant and creates conditions that make it difficult for reproduction to become reestablished.

The fact that only occasional seedlings germinate on burned areas the year after burning indicates that most of the seeds have been destroyed. Furthermore, dense stands of downy chess (Bromus tectorum) usually invade these burns and retard the establishment of bitterbrush seedlings by shading them and competing with them for moisture. Rodents do not cache seeds abundantly in areas covered by downy chess.

Bitterbrush becomes reestablished on burns primarily from seed buried by rodents. A stand of bushes 2 or 3 feet tall can become established on a small burn on a favorable site in about 15 years if rodents

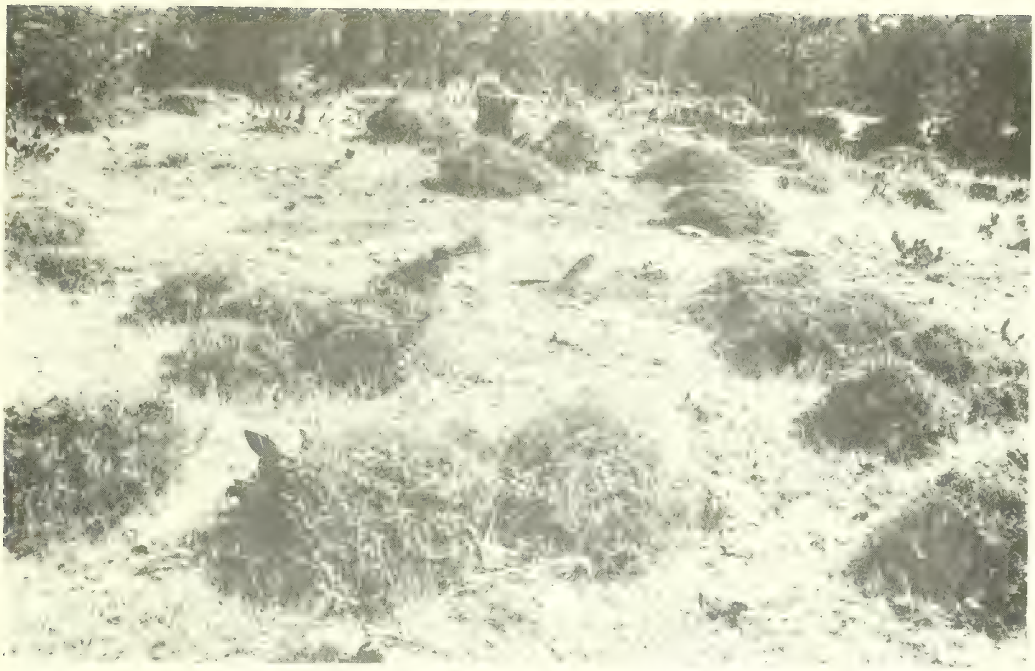


Fig. 5. Shape of bitterbrush characteristic of heavy grazing, particularly by cattle.

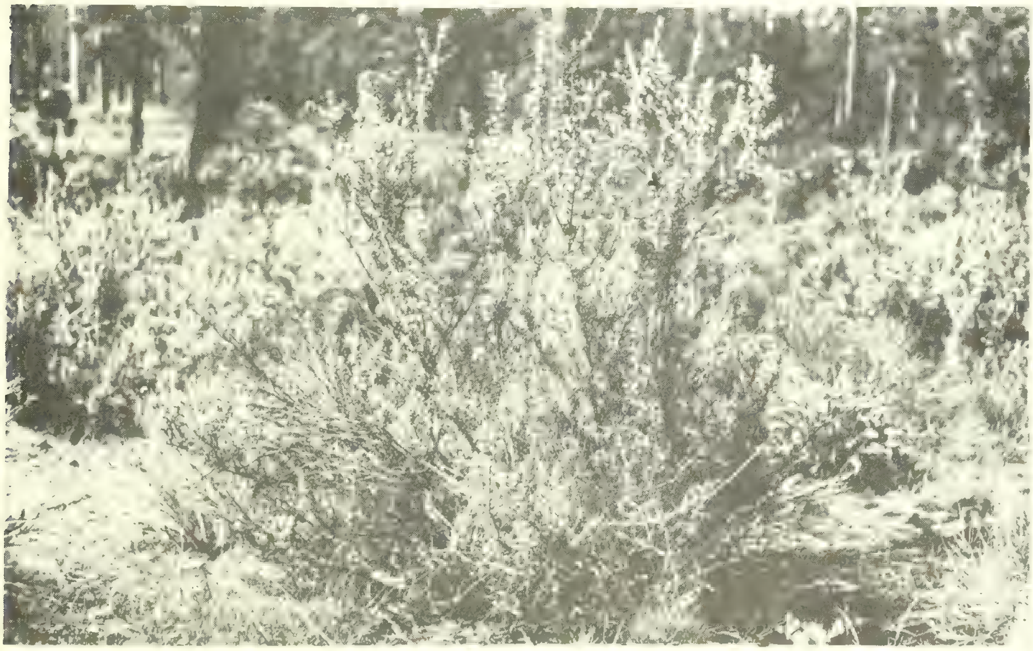


Fig. 6. Form of bitterbrush characteristic of heavy grazing by sheep or deer. Note the flowers on the upper lightly grazed part of the plant.

cache seeds the same year or the year after the fire. Seed caches have been found 200 yards inside burns. It takes many years for bitterbrush to reclaim large burns even with the aid of rodents. But without rodents the burns would not be revegetated by bitterbrush in hundreds of years — if at all.

Weather and other factors.—No doubt weather interferes with the growth and reproduction of bitterbrush at critical growth stages. Often mentioned as causing or contributing to the death of bitterbrush are drought, freezing or sudden extreme changes in temperature, poor soil drainage, or a temporary rise in the water table. Portions of the plant above the snow have been killed by freezing. Bitterbrush seeds fail to develop in some years, owing, it is believed, to unfavorable weather. Seed formation is also prevented by insects that burrow into the developing flower. Galls and rusts on the leaves and stem decay may contribute to the mortality of the shrub.

ARTIFICIAL REVEGETATION

Artificial revegetation offers considerable promise of getting bitterbrush reestablished on many areas where it has been destroyed. The following suggestions are based on experiments and observations to date.

Collection, Storage, and Viability of Seed

Ripe seeds can be collected in July or early August. They should be plump and grayish in color and the red juice in the seed coat should be well solidified. The seeds should be collected from the part of the plant that is producing ripe seed. They mature first on the lower branches and last on the upper and may be stripped off the branches by hand if gloves are worn. The seeds usually fall to the ground within 4 or 5 days after ripening and therefore the collecting time should be closely watched.

It is best to store the seeds in a cool, dry place, preferably in tin containers, until they are used. Seeds stored at 41° F. for 3 years retained most of their initial viability.

The viability of seeds can be tested in a few days in a sample of about 100 seeds from which the embryos have been removed and germinated on blotters or moist sand at temperatures above 55° F. The viable embryos will start to grow in about 2 or 3 days. The embryo can be removed after the seed has been soaked in water for about 4 hours to soften the seed coat. A cut is made with a sharp razor through the top of the seed between the cotyledons to a point just below the widest part of the seed. After the seed coats are pried back from the cut, the embryo can be forced up through the opening when the root end of the seed is gently squeezed.

Fresh seeds that have a well-developed white embryo are usually viable. The embryo can be seen when the seeds are cut in half.

Time of Planting and Seed Treatment

Bitterbrush may be sown in either the fall or the spring. Fall plantings can be made at any time from September until snow covers the ground. Spring plantings should be made early --- from the time snow leaves the ground until the established bitterbrush plants in the vicinity start to put out their first leaves. The soil should not be dried out more than half an inch below the surface.

Either seeds or fruits may be sown in the fall, but in the spring it is best to use stratified seeds. Stratification consists of storing the seeds in coarse wet sand at temperatures between 32° F. and 41° F. for 5 to 8 weeks. When stratified seeds are planted in the field under favorable moisture and temperature conditions they emerge from the ground in 10 to 20 days. In the laboratory stratified seeds gave 60 to 80 percent germination and unstratified seeds gave less than 20 percent germination at temperatures of about 70° F.

Apparently the low temperatures during stratification induce germination. Seeds or fruits planted in the fall, like the fruits that drop to the ground naturally or the seeds that are buried by rodents, are stratified by the low temperatures that prevail from fall to spring. Experimental evidence indicates that stratification in the field takes place mainly during the spring after the snow melts and temperatures rise above freezing. It is probable therefore that unstratified seeds planted early in the spring just after the snow melts would germinate in appreciable numbers.

Stratified fruits gave considerably less germination than stratified seeds in the laboratory. The husk of the fruit seemed to interfere with germination. Experimental planting of fruits in September gave high germination the following spring, however. This suggests that the husks were decomposed sufficiently in the 5 or 6 months from fall to spring to permit germination. Spring planting of unstratified fruits is not recommended, since it is unlikely that the fruit husks would be broken down sufficiently in 1 or 2 months to promote appreciable germination.

Seeds stratified at 41° F. show signs of sprouting after 5 or 6 weeks. They should be removed for planting at this time because if the sprouts are allowed to get much longer they are likely to be broken off in handling. To prevent further sprouting while the seeds are being transported and handled in the field they should be packed in ice. They may be kept in this way for a week to 10 days.

Depth and Method of Planting

In both spring and fall the seeds should be planted 1/4 to about 1 1/4 inches deep in the soil. They may be sown broadcast and disked or harrowed into the ground or they may be planted in shallow furrows or in spots by hand or with a corn planter. The most practical method will depend on ground conditions -- on degree of slope, the amount of rocks and vegetation, down logs, and other obstructions.

Survival of Seedlings

The results from both fall and spring experimental plantings indicate that if either seeds or fruits are sown at the proper depth and at the proper time only a small percentage is likely to be found and destroyed by rodents. More than half of the seeds can be expected to germinate. However, many of the young seedlings are destroyed by rodents, insects, game, or unfavorable weather during the first month of growth. This loss occurs usually before the livestock grazing season starts. Even under favorable conditions as many as 90 percent of the seedlings may die by the beginning of the third year of growth. It is estimated that less than 5 percent of the planted seed will produce mature plants. In artificial reseeding enough extra seed should be sown to offset this high mortality. The number of seedlings to survive will depend on the site -- on the moisture-holding capacity of the soil, the amount of spring and summer rain, and the amount of vegetation competing with the seedlings the first season or two when they are developing their root systems.

Selection of Planting Site

Reseeding of bitterbrush should be tried first on areas that are known to have supported bitterbrush in the past or still support some of the plants. Within the range of bitterbrush the chances of getting successful establishment of seedlings from artificial reseeding differs from one place to the next. The ages of the plants in ungrazed or lightly grazed bitterbrush stands, near and comparable in site to one proposed for planting, can be used as a guide in judging the suitability of a particular area for reseeding. If the plants in these stands range in age from young to old and differ in age by only 1 or 2 years it shows that seedlings have become established at frequent intervals in the past. This indicates that the chances of survival of at least some of the seedlings from plantings on the site would be high. On the other hand if the number of years between age groups is large, 5 or more years, the odds against seedling survival would be 5 or more to 1. The ages of the plants in a stand used to get an indication of seedling survival can be determined by counting the annual rings in the stems of plants on sample strips about 18 inches wide and 4 or 5 chains long. The plants should be pulled up by the roots and the stems sectioned for the ring counts.

Artificial reseeding is always a gamble primarily because of the uncertainty of weather, but careful selection of the planting site will increase the chances of success. Until more is known about the subject bitterbrush reseeding should be carried out on a small scale on sites that are most favorable for seedling establishment.

Intensity and Coverage of Planting

There are from 18,000 to 24,000 seeds and about 14,000 to 20,000 fruits in a pound. In broadcast planting 2 pounds of seed or 3 pounds of fruit per acre seems adequate. This provides one seed for each square foot or two of ground surface. In spot planting 4 or 5 seeds may be sown in one place at intervals of 4 or 5 feet along lines spaced 4 or 5 feet apart. In furrow planting 1 or 2 seeds should be distributed over each linear foot of line.

Rodents are known to carry seed as far as 200 yards from the nearest bitterbrush plants, but they cache intensively usually within only 100 feet of the seed supply. Therefore planting-strips 10 to 20 feet wide spaced about 200 feet apart should provide ample plants and seeds for future caching in the interspaces.

SUMMARY

Bitterbrush is the most important range browse east of the Sierra Nevada-Cascade ranges in California. Over large areas it has been destroyed or damaged by such factors as fire, heavy grazing by livestock and game, defoliation by tent caterpillars, girdling by rodents, or weather conditions. Not enough reproduction is becoming established to perpetuate the stand in many places.

Bitterbrush reproduces mainly from seed and the stands are established chiefly from seeds buried in caches by rodents. The natural dissemination of bitterbrush seeds and the spread of the plant over wider areas is chiefly the result of rodent caching. The quick reestablishment of bitterbrush on many small burned areas is due to the caching of bitterbrush seed on these areas by rodents.

Close grazing by livestock each year is probably the principal cause of the widespread deterioration of bitterbrush in California. It is harmful primarily because it reduces the seed supply, preventing the establishment of sufficient young plants to maintain the stand. It is estimated that 40 percent or more of the twig growth should remain on the plant each season to insure adequate seed production and good plant vigor.

Heavy use resulting from winter grazing of bitterbrush by mule deer combined with summer grazing by livestock is damaging bitterbrush in some localities. Defoliation of bitterbrush by the Great Basin tent caterpillar also causes heavy destruction of bitterbrush. Plants weakened by grazing or previous caterpillar infestations are more easily killed by defoliation than plants not weakened by these causes.

Fire kills bitterbrush in most instances in California. Valuable bitterbrush stands should be given full protection from fire.

Artificial reseeding trials offer considerable promise for the reestablishment of bitterbrush on many sites where it has been destroyed. Germination from both fall and spring plantings can be expected in most years. However, survival of the seedlings depends also on adequate soil moisture throughout the first growing season and protection from rodent damage and heavy grazing. Survival may be expected on sites that adjoin areas where some natural reproduction has become established in most years.

Additional facts on growth, reproduction, utilization, and artificial reseeding of bitterbrush are needed for the satisfactory management of this valuable browse. Such information can be used to increase livestock production and improve the general condition of ranges.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE TENN.

Research Note No. 35 October 8, 1943

A METHOD OF ESTIMATING GRAZING USE OF BITTERBRUSH

By

A. L. Hormay, Associate Forest Ecologist[1]

Not more than 60 percent of the current twig growth of bitterbrush (Purshia tridentata) should be grazed each season if the plant is to retain its vigor and produce abundant seed.[2] A simple method of determining the grazing use of this valuable browse is outlined below. It consists in estimating the amount of current twig growth grazed on marked bushes on sample plots.

Size and shape of plot

The sample plots should be all the same size, and narrow and long enough to include 20 to 25 average-size bitterbrush plants. Plots 20 inches wide and 2 or 3 chains long -- approximately 0.0050 to 0.0075 acres in size -- have been used in stands of about 0.2 density.

Number of plots

The number of plots needed depends on the variability of the bitterbrush stand and the variability of grazing rather than on the area of the stand. Twenty- to twenty-five plots of the size and shape described above should give a reliable estimate of grazing use. More plots may be used but it is inadvisable to use fewer than 20.

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[1] Mr. F. D. Douthitt, Division of Wildlife and Range Management, Region 5 assisted directly in the field work of this study. His cooperation, including suggestions on the manuscript, has been very helpful.

[2] Hormay, A. L. 1943. Bitterbrush in California. Calif. Forest & Range Expt. Sta. Res. Note No. 34. 13 pp. (Multilithed.)

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Distribution of plots

The area of the stand is divided into as many approximately equal-size blocks as the number of plots to be used. One plot is located in each block in a representative area reasonably close to roads and trails to avoid excessive travel to and from the plots. Each plot is numbered and marked.

Identification of bushes

Each bitterbrush plant growing on the plot is marked with a durable numbered stake driven into the ground on the same side of each bush where it may be easily located. Metal tags may be used, but they are hard to find on the bushes. If used the tags should be placed in approximately the same place on each plant on a large branch that will not be removed by grazing.

Measurements of the bushes

The following records are made of each marked bush:

(1) Measurement of the average diameter of the entire crown to the nearest inch. Two or more measurements may have to be made in different directions across the crowns of irregularly shaped plants to arrive at an average.

(2) Estimate in inches of the average length of all ungrazed twigs.

To aid in judging average twig length measure several twigs on different parts of the plant with a ruler.

(3) Estimate in percentage of the total amount of twig growth grazed on the bush.

Differences in leafiness of the twigs at different times of the season should not be allowed to distract the eye from estimating the proportion of the actual length of the twigs that have been grazed. In the fall the twigs are covered with green or drying leaves. In early spring they are bare but a few weeks later, before the new season's twig growth starts, they are again clothed with green leaves.

Calculation of utilization

In order to calculate percentage utilization of a bush, a plot, or the area studied, values representing the amount of forage produced and the amount grazed have to be obtained. In the present method these quantities are expressed by arbitrary numbers. For example, the amount of forage produced on a bush is expressed by the product of the area of the plant crown and the average ungrazed twig growth on the bush. This product is correlated with volume and yield but is not a direct measurement of either. It is simply a number that can be compared directly with similar numbers calculated for other bushes and serves the purpose of permitting relative comparison to be made in total production and total utilization as well as percentage utilization. Percentage utilization figures are calculated for each plot and for the area as a whole. The utilization of the area as a whole is the average of utilization percentages of all the plots.

To determine the percentage utilization of a plot --

1. Multiply the area of the plant crown by the average ungrazed twig growth of each plant and add the results for all the bitterbrush plants on the plot. This quantity expresses the total forage produced.

2. Multiply the products obtained for each plant in step 1 by the estimated percentage utilization of the twig growth of each plant and add the results for all bitterbrush plants on the plot. This quantity expresses the total forage grazed.

3. Divide the total forage grazed by the total forage produced and multiply by 100. This gives the percentage utilization of the plot.

Some results from field use of this method

The method described above was used to measure grazing of bitter brush on the Modoc National Forest during the summer and winter seasons of 1940 and 1941. During the summer the area was grazed primarily by sheep and during the winter by deer. The stands studied had an average density of 0.2 or 0.3. Utilization estimates were made in the fall after the livestock were taken off the range and current twig growth was completed and again the following spring before the livestock were put back on the range and before new twig growth started.

The figures showed that by October (1940) 19 percent of the current twig growth of bitterbrush had been utilized by sheep. Deer grazing in this locality was negligible during the summer because of the small population. From October 1940 to May 1941 deer ate 51 percent of the total twig growth produced the previous summer. Sheep and deer together ate 70 percent of the seasonal growth. In the next season 71 percent of the twig growth was utilized, 38 percent by sheep in summer and 33 percent by deer in winter. A picture of the summer use of bitterbrush by sheep and the winter use by deer was thus obtained for this area. It should be mentioned that in sparse bitterbrush stands even a few deer will graze the scattered plants closely, and utilization by livestock and by game cannot be differentiated.

The reliability of the method depends principally on the number of plots used and on the accuracy of the estimates of twig length and utilization of each bush. It can be applied to other browse species on which current twig growth is easily recognized.

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STORAGE AND GERMINATION OF CALIFORNIA CORK-OAK ACORNS

By

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INTRODUCTION

Cork-oak acorns are known to be extremely perishable, but exact information on their storage is surprisingly meager. Spanish and French literature on the subject is disappointingly general. Recently some fundamental work has been done in Russia on cork oak, but great climatic and ecologic differences between southern Russia and California warranted an independent study of handling cork-oak acorns under local conditions. The numerous cork-oak trees now growing in California produce an ample quantity of acorns both for experimental work and, if economically handled, for moderate-scale field planting. The ready availability of fresh acorns here in California is an advantage in experimental storage and germination. On the other hand, gathering acorns from widely scattered trees whose pedigree is not known to the experimenter is a serious drawback in research.

In Europe cork is harvested from three species of oak: *Quercus suber* L., *Q. occidentalis* Gay (which is considered by some as a variety of *Q. suber*), and *Q. pseudosuber* Santi (which is a hybrid between *Q. suber* and *Q. cerris*). *Q. pseudosuber* is of a limited distribution and it produces cork of an inferior quality. It is doubtful if this oak has been introduced to California. *Q suber* grows in Europe under environmental conditions very different from those under which *Q. occidentalis* grows. The two trees differ a great deal in their height, their latitudinal and altitudinal distribution, and their soil and climatic requirements. Besides these two major forms there are many ecologic races of cork oak.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Cork oak has been grown in California since the fifties, and at present there are several groves and numerous individual trees scattered throughout the warmer parts of the State. Cork-oak trees are found in southern California, in the Sacramento and San Joaquin valleys, and in some localities of the central coastal regions, such as in the vicinity of San Francisco Bay, Napa, and Sonoma. The most northern localities that cork oak was planted on the coast appear to be near Fortuna and in the interior in the Sacramento valley near Chico. In the Sierra Nevada foothills cork-oak trees are found as high as 2,600 feet above sea level.

In the introduction of cork oak to California, apparently no attempts were made to plant different varieties of cork oaks in appropriate places. Judging from the size of acorns and the time of fruiting, it appears that many different varieties of cork oak were introduced to California. To consider the taxonomic and ecologic variations of California cork oaks is beyond the scope of this paper, but it is necessary to point out that the acorns used in the experiments did not necessarily belong to the same variety of cork oak. The material used was by no means taxonomically homogeneous.

In a preliminary study the heterogeneity of the acorns did not seem too important, since the acorns received from many localities exhibited similar tendencies in germination and storage. In further studies it appears desirable to use more homogeneous material.

CHARACTERISTICS OF CALIFORNIA CORK-OAK ACORNS

Cork oak belongs to the white oak group and its acorns possess most of the distinguishing characteristics of the group. White-oak acorns, including those of cork oak, usually germinate in the autumn, and black-oak acorns usually do not germinate until spring. In other words, the former do not exhibit the phenomenon of dormancy, but the latter do and are accordingly characterized by delayed germination (Korstian, 6).

Cork-oak acorns germinate promptly after they fall from the trees, provided, of course, that the ground is moist. Although they germinate slowly at temperatures as low as 32°F., the optimum temperature for their germination is between 59° and 77° F. (Pravdin, 8).

In some respects, however, germination of cork-oak acorns differs considerably from that of other oaks, and this difference has an important bearing on their practical handling. In all oaks germination begins with longitudinal splitting of the shell (fruit coat) at the apex of the acorn. The radicle then emerges and the petioles of the cotyledons elongate so that they carry the plumule outside of the shell (Korstian, 6). In most oaks the hypocotyl is very short. In _Q. robur_ it is only 2 to 3 mm. long. In _Q. pedunculata_ also it is almost wanting; 2 months after germination, when the shoot reaches 11 cm. and the root is 33 cm. long, the hypocotyl is only 0.3 cm. long (Kirchner et al., 5). The behavior of cork oak is different. Germination is prompter than in many other white oaks. The root emerges very soon after the acorns are planted — in 2 or 3 days. The shoot appears in 7 to 10 days after planting. From table 1 it is seen that the appearance and growth of the shoot in relation to the root vary a great deal.

Table 1.- Shoot and root length of a few cork-oak seedlings

Length in cm.		
Shoot	Root	Root-shoot ratio
0.25	15.5	62 : 1
0.75	9.0	12 : 1
1.0	5.0	5 : 1
5.5	23.5	4 : 1

The most interesting thing about the germination of cork oak is that the first 10 - 15 cm. of the "root" is not a root proper, but the hypocotyl; it has the anatomical structure of a stem and not of a root (Pravdin, 8). At 10 to 15 cm. below the cotyledons the real root appears. The first stage of germination consists of intercalary growth. This intercalary growth takes place in the zone in which the cotyledons are attached to the stem. Two rows of buds are formed on the whole length of the hypocotyl. When the plumule or the young shoot is removed these hypocotyl buds develop into shoots, as shown in figure 1. Root hairs are formed frequently on the hypocotyl. It is rather a wide spread opinion that decapitated cork-oak seedlings give root sprouts. In view of the facts noted above, it is seen that of the subterranean parts of the seedlings only the hypocotyl forms epicormic 1/ buds that may give rise to shoots. The root proper does not produce epicormic buds.

Cork-oak acorns used in these experiments were collected chiefly in two California localities: from a 38-year-old plantation near Chico and from 20-year-old roadside trees at the University of California, Davis, in November and December 1942. In room-storage tests, acorns collected in the Napa valley were used. Smaller lots were received from several other places in California, but the acorns of these lots were used only for determining variations in size and not for storage or germination tests.

The acorns collected in California in the autumn of 1942 varied greatly in size and accordingly in number per pound. The weight of 100 acorns in grams and the number of acorns in a pound are given in table 2 for several representative samples.

1/ Since the writer is in doubt whether the buds formed on the hypocotyl are dormant buds or adventitious ones, the more general term "epicormic" is used.

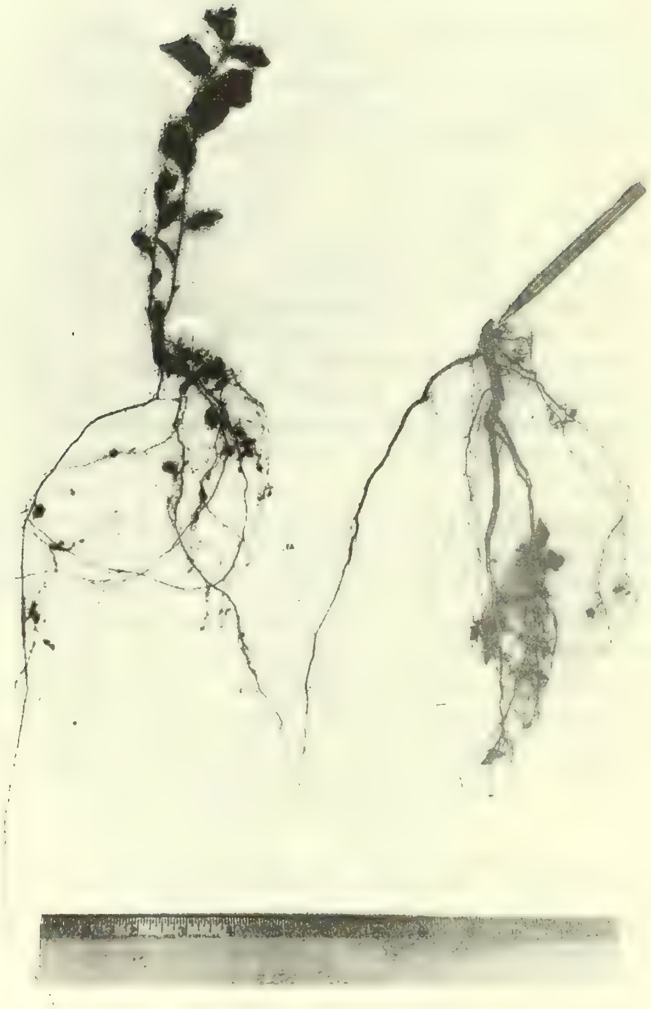

Figure 1.- Development of shoots from hypocotyl buds of decapitated cork-oak seedlings.

Table 2.- Weight of 100 cork-oak acorns in grams and number of acorns in a pound of several lots collected in California in 1942.

Origin	Weight of 100 acorns	Number in a pound	Size of acorns
	grams		
Rich Ranch, Kern County	805	56	Extra large
State Hospital, Napa County	675	67	Large
University of California campus, Davis, Yolo County	512	89	Average
	448	101	Average
Bidwell Park, Chico, Butte County	375	121	Average
" " " " "	315	144	Average
Street tree, Sonora	165	275	Extra small

Moisture content of cork-oak acorns and its relation to germination

The moisture content of one lot of fresh acorns was determined at the San Dimas Experimental Forest [2]. Some of the acorns were collected from the tree, but the majority were picked up from the lawn within 5 days after they had fallen from the tree. The moisture of the acorns, determined by the xylene distillation method the day after collection, was 75 percent of the dry weight of the acorns.

At Berkeley the writer determined the moisture content of four lots of cork-oak acorns by drying 100 acorns of each lot at 221° F. for 24 hours. The moisture content was calculated on the basis of the oven-dry weight of the acorns. The results are given in table 3.

Table 3.- Moisture content of four lots of California cork-oak acorns

Origin and lot number	Date of collection (all 1942)	Date of arrival at laboratory (all 1942)	Temperature during storage	Date of determining moisture content	Moisture content, based on oven-dry weight
					Percent
Chico #1	Nov. 17	Nov. 25	32° F	Dec. 22, 1942	57
Chico #2	Nov. 17	Nov. 25	32° F	Dec. 23, 1942	73
Davis #1	Dec. 13	Dec. 15	40° F	Jan. 4, 1943	67
Davis #2	Nov. 16	Nov. 27	40° F	Nov. 28, 1942	77

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[2] Jerome S. Horton of the San Dimas staff made this determination.

The moisture content of Chico lot #1 seems to be abnormally low and of the other lots about equal. The acorns of Chico lot #1 and Davis lot #1 apparently lost some moisture in transit. Judging by Horton's data and by the figures obtained by the writer with Chico lot #1 and Davis lot #2, it may be concluded that moisture content of the ripe acorns, when they begin to fall from trees, is between 75 and 80 percent.

In order to determine the moisture content at which cork-oak acorns lose their viability, further tests were made with the above-mentioned lots of acorns. At the time of determining the initial moisture content, a quantity of acorns was brought to the laboratory (where the temperature was about 77° F.) and spread on a bench. At predetermined intervals 100 acorns were withdrawn from each lot; 50 were used for determining moisture content and 50 for determining germination capacity. Germination tests were made in the greenhouse in which the temperature fluctuated between 60° and 80° F. The results of these tests are shown in table 4 and in figure 2.

Table 4.- Loss of viability of California cork-oak acorns with loss of moisture in storage.

Origin and lot number	Moisture and germination	Days stored in laboratory at 80° F.										
		0	2	3	4	5	6	7	8	9	10	12
					Percent							
Chico #1	Moisture	58	49		40		32		28		24	22
	Germination	76	60		20		5		0		0	0
Chico #2	Moisture	73		60			46		35			30
	Germination	80		64			38		4			0
Davis #1	Moisture	67	56			45		38				33
	Germination	92	58			34		10				0
Davis #2	Moisture	77	68				54				38	35
	Germination	90	64				29				5	0

The following conclusions can be drawn from these experiments:

1. The moisture content of freshly collected acorns is apparently between 70 and 80 percent.

2. A moderate (perhaps 10 percent) loss of moisture between harvesting and planting acorns is not detrimental to the viability of the acorns.

3. In a warm room loose cork-oak acorns lose moisture very rapidly and after only 5 or 6 days most of the acorns perish.

4. When the moisture content of the acorns reaches 30 to 35 percent, they lose their viability.

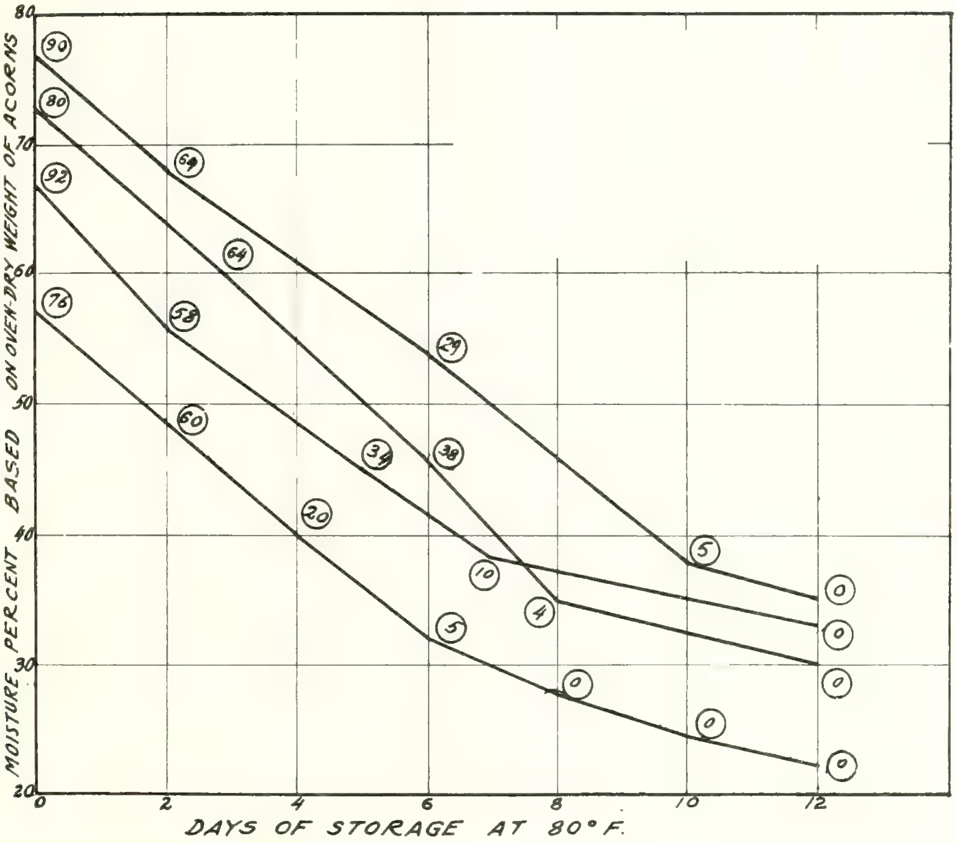

Figure 2.- Loss of moisture and decrease in germination with storage of cork oak acorns. (Figures in circles denote germination percentage.)

In order to preserve a high degree of viability in cork-oak acorns, their moisture content should be kept well above 35 percent and as close to the original moisture content as possible. No attempt should be made to germinate cork-oak acorns when their moisture content is below 30 to 35 percent.

EXPERIMENTS WITH STORAGE OF CORK OAK ACORNS

As cork-oak acorns are extremely perishable, some experiments were started late in 1942 to determine the best conditions for storage. The following storage conditions were tested:

Warm room storage (70° 80° F.)

Loose, in laboratory. See preceding discussion of moisture content of cork-oak acorns.

Paper bags. For this test 100 acorns were placed in each bag.

Mixed with sand in an open wooden box.

In airtight jars, in laboratory. See discussion of preparation of cork-oak acorns for shipment.

Cold storage (32° F.)

Paper bags. Same procedure was used as in warm-room storage.

Mixed with sand and kept in airtight 5-gallon can. The acorns were mixed half and half by volume with air-dry sand.

Bulk, in an air-tight 5-gallon can.
This experiment was started 4 weeks later than the other experiments; during that time the acorns were stored in a burlap sack at 40° F.

In moist peat, in a 10-gallon can.
For this method of storage, known as stratification, an ash can was provided with an opening at the bottom, and a central aeration well was made of coarse screen, in order to assure free circulation of air. The can was loosely covered with a lid.

In 100-pound burlap sacks.
This was an incidental test of a lot of 10 sacks brought from Chico early in January and stored in a commercial cold-storage house for 10 weeks prior to distribution.

In the warm-room storage test, acorns collected in the Napa valley were used. In the cold-storage tests acorns collected at Davis were used. Using cork-oak acorns from two different localities in one experiment was perhaps not desirable, but since acorns received from many localities in California show very similar behavior in storage and germination, the results are considered reliable enough for general application.

The procedure for testing the viability of acorns stored under different conditions was as follows: An initial test of 400 acorns was made and afterwards 100-acorn lots were withdrawn from storage at prescribed intervals and germinated in the greenhouse in wooden flats filled with a mixture of sand and peat. Germination counts were made and the behavior of the germinating acorns was observed. The acorns were considered to have germinated when a normal and healthy root emerged from the shell to about one-half inch. The shoot usually appeared from 1 to 2 weeks after the emergence of the root. Under certain circumstances the rooted acorns never developed a shoot. This phenomenon will be discussed later. The results of the storage tests are presented in table 5.

In a warm storage room viability of cork-oak acorns kept in paper bags decreased rapidly and after 2 weeks it reached a very low level. The acorns kept in an open container filled with dry sand retained their viability for a longer time; cork-oak acorns can be kept under these conditions for perhaps 10 days, but not longer. Unfortunately room storage in airtight containers was omitted from this series of tests. Later experiments of this kind (see Preparation of cork-oak acorns for shipment, p. 14) showed that in airtight quart jars the acorns can be kept at room temperature of about 77° F. for 2 weeks.

Keeping the acorns in small individual paper bags in cold storage was also found to be unsatisfactory. Apparently the acorns lose moisture too rapidly under these conditions. On the other hand, if stored in 100-pound burlap sacks they can be kept in cold storage for as long as 10 weeks without appreciable loss of viability. Keeping oak acorns in a moist medium with an abundance of air (i.e., stratification) has been advocated by Johannsen(4). In the present study, stratification of cork oak acorns as a means of storage was found unsuitable. Germination took place even at 32° F., although it progressed but slowly. After 4 months of stratification the tips of emerged roots turned brown and died. At first this did not affect the development of seedlings. New roots were formed from the hypocotyl and since the shoot bud was not killed the germinating acorns developed a healthy top. But gradually the rot crept up from the root and when the plumule was affected, the acorns became unsuitable for planting. After 32 weeks of stratification only 36 per cent of the acorns developed a shoot.

Treatment of stored cork-oak acorns with naphthaleneacetic acid.

Guthrie (3) has shown that naphthaleneacetic acid has an inhibiting effect on the development of buds of potato tubers. It appeared desirable, therefore, to try this chemical as a germination-inhibitor of stored cork-oak acorns. On December 17, 1942, two 1-gallon jars were filled with freshly collected acorns. In one jar a small beaker was inserted containing 2.5 grams of crystalline alpha-naphthaleneacetic acid; the acorns in the other jar remained untreated and served as control. Both jars were tightly stoppered, and 100 acorns were withdrawn from the jars at certain intervals. At the time of writing this report (September 1943), control acorns still gave about 100 percent germination. The effect of naphthaleneacetic acid is shown in table 6 and figure 3.

Table 5.-- Germination of California [illegible] acorns stored under different conditions.

Storage conditions	Germination percentage after different periods of storage													Remarks
	Weeks													
	0	2	4	6	8	10	12	16	20	24	28	32	34	
Warm-room storage														
Paper bags	96	15	5		0									
Sand, open container	93	58	37		12		4	0						
Cold storage														
Paper bags	100	88	21		[illegible]									
Mixed with dry sand in airtight 5-gal. cans	100	100	100		[illegible]		96	98	96	100		96		In progress
Bulk, in airtight 5-gal. cans	85		84		8[illegible]		84		33		84			In progress
Stratified in moist peat in 10-gal. cans	100				100			98[1]		9[illegible][1]	60	36		In progress
Burlap sack[2]	100		100				9[illegible]							

[1] Germinated in storage. Tips of roots dead. Development of additional roots and of the shoots is satisfactory.

[2] The acorns used in this test were withdrawn from a large shipment brought from Chico early in January and stored in a commercial cold-storage house in burlap sacks.

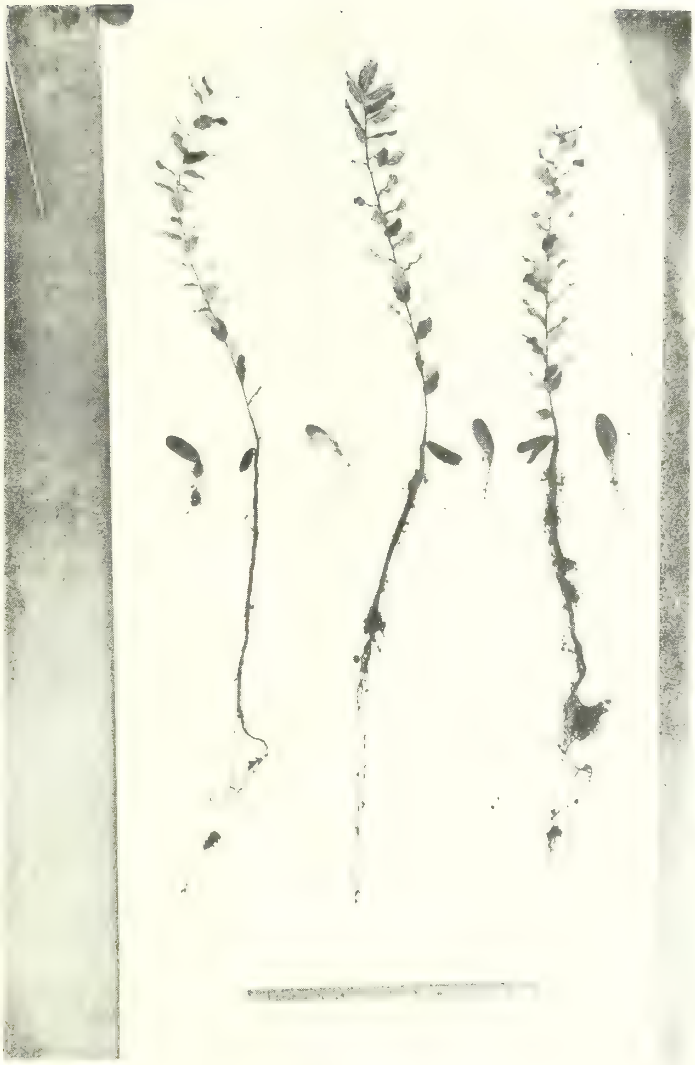

Figure 3.- Effect of naphthaleneacetic acid on germination of cork-oak acorns. Untreated acorns developed normally; those kept in presence of the acid for 132 days failed to develop shoots.

Table 6.- Germination and development of stored cork-oak acorns treated with naphthaleneacetic acid.

Date stored	Length of storage	Days germinated 1	3	7	21	28	63	Development
	Days			Percent				
Dec. 17	0	0	90	100				All developed shoots.
Feb. 1	45	0	88	100				All developed shoots.
Mar. 1	73	0	94	100				All developed shoots.
Mar. 29	102	0	0	3	56	84		Only 14% developed shoots
Apr. 28	132	0	0	0	0	1	36	No shoot development.
May 24	158	0	0	0	0	0	8	No shoot development.
June 19	184	0	0	0	0	0		No shoot development.

It is seen from table 6 that 73 days of storage in the presence of naphthaleneacetic acid has no effect on germination and immediate development of the acorns. The shoots developed normally. Acorns kept in the presence of the chemical for more than 73 days differed markedly from the control acorns. One week after planting, 82 percent of the control acorns developed normal roots averaging 35 mm. in length, but only 14 percent of the treated acorns developed roots, these averaging 21 mm. in length. The longer the acorns were kept under the influence of naphthaleneacetic acid the more evident became the inhibiting effect of the chemical on the development of the acorns. Apparently it was killing the meristems of both shoot and root; when the root meristem was killed additional roots were formed above the root's tip. These roots had the appearance of distorted appendages. In many cases when plumule, hypocotyl, and root were killed, filiform roots developed on the petioles of the cotyledons. This interesting phenomenon will be discussed later.

Treatment of acorns with naphthaleneacetic acid has a peculiar effect. First, it arrests development of the shoots; after more prolonged treatment it kills both root and shoot apical meristems but it does not kill cotyledons. When untreated acorns are placed in germination flats they either germinate or rot, depending on their viability, but when acorns are kept in cold storage in the presence of naphthaleneacetic acid say, for 150 or 180 days, and are subjected to germination tests, they neither germinate nor rot.[3] They rupture the fruit coat, increase in size, and acquire a dark green color. Many of them eventually develop fibrous roots. Some of these rooted acorns have been under observation for 8 months and they look as healthy as at the beginning of the experiment. Since the cotyledons have acquired a green color — i.e. developed chlorophyll — they can photosynthesize and will probably live for a long time. However, they cannot develop bud-producing initials. In this respect they resemble leaves of certain plants, such as Ficus elastica, which can develop roots but not shoots.

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[3] A similar phenomenon occurs when the plumule and the hypocotyl are injured by fungi.

The capacity of developing roots on cotyledons has apparently never been observed on plants other than cork oak. This phenomenon was described by Pravdin (8) and has been verified during the present experiments. (Pravdin's work was not known to the author at the time the experiments were performed.) Although of no immediate practical importance, this unusual phenomenon is of considerable scientific interest and value.

Since cork-oak acorns have a peculiar capacity to develop roots without developing shoots, it appears advisable at least in practical work to judge viability of the acorns only by their capacity to develop shoots.

The experiment indicates that moderate treatment with naphthaleneacetic acid may be used to prevent immediate germination of newly harvested cork-oak acorns. More experiments of this kind are planned for the 1943 harvesting season.

Treatment of stored cork-oak acorns with some other substances

Naphthaleneacetic acid is not the only chemical material that retards the growth of plants. It has been found by Denny (1) and Guthrie (3) that derivatives of this acid, such as its methyl ester, are even more efficient in arresting growth than the acid itself. Marth (7) used also naphthaleneacetonitrile for checking the bud development of stored rose bushes. Sell et al. (9) prolonged dormancy of tung tree buds by treating them with naphthaleneacetic amide. It appears that many other substances that interfere with the orderly metabolism of plants affect their growth. Gray and Fuller (2) investigated a possible effect of mercury vapors on germination of various vegetable seeds; they reported that the seeds kept in the presence of mercury for 6 months suffered no ill effect. It has also been shown that growth-regulating substances are found in tar and in petroleum oil. It appeared of interest to investigate the effect of these substances on cork-oak acorns. Methyl ester and acetonitrile of naphthaleneacetic acid were not obtainable, but a test was made with the other substances mentioned — mercury, asphaltum varnish, and acetamide of naphthaleneacetic acid.

Four 1-quart jars were filled on March 12 with acorns of high viability (previously stored in dry sand in an airtight can). To the first jar was added 10 cc. of mercury, to the second jar an equal amount of asphaltum varnish, to the third jar 2.5 grams of acetamide of naphthaleneacetic acid. The acorns in the fourth jar were not treated and served as a check. After 2 months acorns were withdrawn from each jar and germinated. The results of this test are presented in table 7 and figure 4.

Table 7.- Germination and development of cork-oak acorns stored for 2 months under different treatments.

Treatment	Germination 10 days	 18 days	Number of seedlings with tops	Average[1/] height of seedlings	Remarks
	Percent	Percent			
Not treated	96	98	43	5.9 cm.	
Mercury	100	100	46	7.8 cm.	
Asphaltum varnish	98	98	40	3.4 cm.	
Acetamide	82	94	28	2.4 cm.	

1/ Measurement of the tops was made on June 17. A statistical analysis showed the difference in height growth to be highly significant.

From the germination behavior of the acorns withdrawn 2 months after the beginning of the experiment, it appears that acetamide definitely retarded development of the roots and the shoots. Asphaltum varnish retarded development of the shoots, although the roots developed normally. The effect of mercury was unexpected: the acorns treated with this substance germinated the best and showed the most vigorous root development and the best shoot growth when measured 1 month after planting the acorns. The results of this experiment warrant a further investigation of the effect of acetamide of naphthaleneacetic acid as a growth-arresting agent for stored acorns.

PREPARATION OF CORK-OAK ACORNS FOR SHIPPING

Maintaining viability of cork-oak acorns during transport from the place of harvest to the locality of planting is essentially a problem of storage. Experience with storage of cork-oak acorns suggests that if freshly collected acorns are packed in burlap sacks holding about 100 pounds, they can be shipped by truck to any point in the State where cork oak is to be planted. Low temperatures prevailing during the ripening season of the acorns and a distance measured by only a few days of travel assure perfect preservation of the viability of the acorns. If the shipment of acorns is delayed and made by freight train for a long distance, the problem becomes more difficult.

Experiments to determine the maintenance of viability in transit consisted in storing the acorns in a warm room under different conditions. In one experiment freshly collected acorns were dipped in either melted paraffin or liquid wax and kept on the laboratory bench for 19 days.[4/]

4/ Pravdin (8) reported that he put lots of 50 cork-oak acorns in small metal containers and poured melted paraffin into the containers. After 30 days of room storage, the acorns gave 100 percent germination.

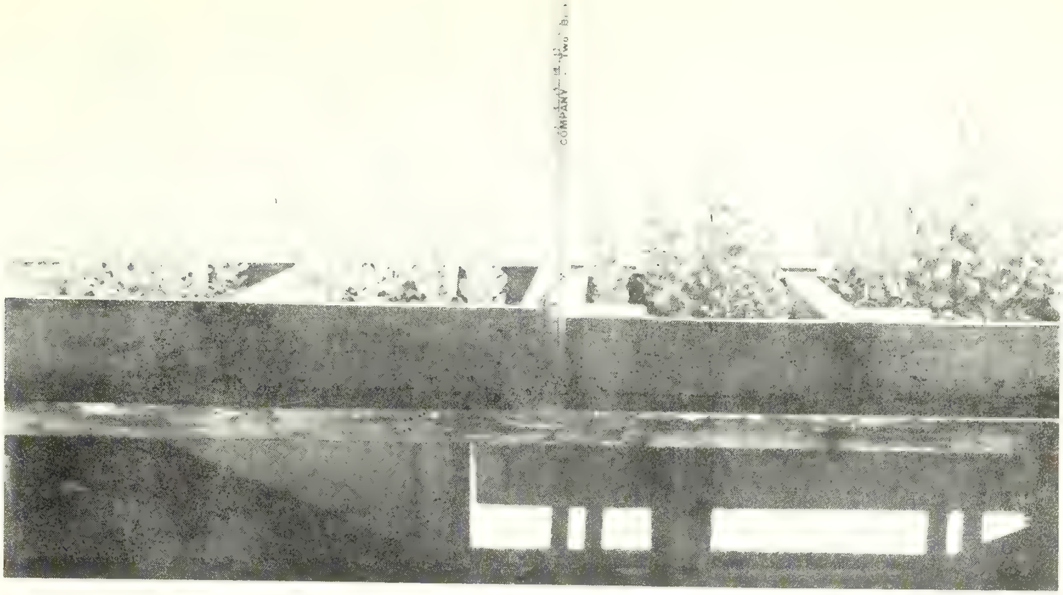

Figure 4.- Development of cork-oak seedlings after treatment of the acorns for 2 months with different substances. Acorns were (1) treated with acetamide of naphthaleneacetic acid, (2) treated with asphaltum paint; (3) untreated; (4) kept in presence of mercury.

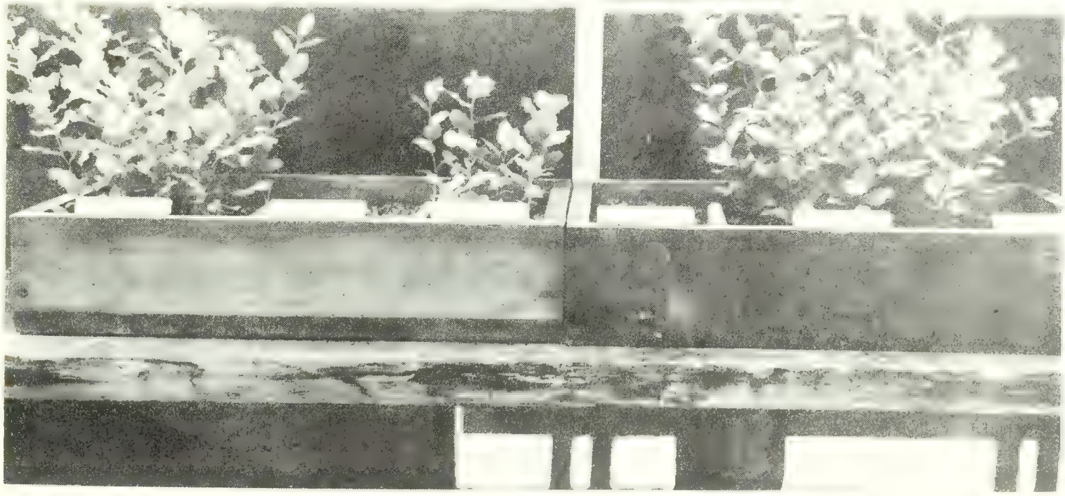

Figure 5.- Seedlings grown from cork-oak acorns treated and untreated with commercial wax emulsion. Treatments and containers (described in table 5) were untreated, jars; (2) wax and naphthalenaecetic acid, bags; (3) wax and naphthaleneacetic acid, jars; (4) wax, bags; (5) wax, jars; (6) untreated, bags. Note checking of growth of seedlings when naphthalenaecetic acid was added to wax emulsion.

Germination of the paraffin-dipped acorns amounted to 54 percent in 7 days; those dipped in liquid wax did not germinate; untreated freshly collected acorns gave 94 percent germination.

In another experiment the acorns were kept for 2 weeks under conditions shown in table 8. The liquid wax used in these tests as a preserving agent was a commercial wax emulsion used previously by several workers to prevent the escape of moisture from plant material. In the present experiments 1 part of the emulsion was mixed with 2 parts of water; the acorns were dipped in the emulsion and allowed to dry for 30 minutes before they were put in containers.

Table 8.- Storage of cork-oak acorns under conditions to be used in shipment.

Treatment and container for 2-week period	Germination in 7 days[1]
	Percent
Untreated	
Paper bags	0
Airtight quart-size glass jars	96
Dipped in 1:2 solution of commercial wax emulsion	
Paper bags	0
Airtight quart-size glass jars	90
Dipped in 1:2 solution of commercial wax emulsion to which 0.5 grams of napthaleneacetic acid had been added.	
Paper bags	0
Airtight quart-size glass jars	94

[1] Control acorns, taken directly from cold storage and planted, gave 96 percent germination.

Dipping in a solution of commercial wax emulsion did not prevent the loss of moisture from the acorns. Packing acorns in airtight jars preserved their original viability. A slight odor of fermentation in the jars, resembling the odor of apples, was probably due to spoiling of one or two acorns. It is evident from table 8 that treatment of jar-stored acorns with wax emulsion is not necessary. Addition of naphthaleneacetic acid to wax emulsion caused the usual retarding effect on development of the acorns. The results of this experiment are shown in figure 5. The photograph was taken 3 months after planting.

In view of our present experience, however meager, the shipping of acorns in bulk should be avoided. The best method of shipping cork-oak acorns is to pack them in 100-pound burlap sacks and keep them under refrigeration (from 32° to 40° F.) while in transit. Small samples of acorns packed in airtight quart-size containers can withstand at least a 2-week period in transit.

SUMMARY AND CONCLUSION

This report covers the first year of experimental work with germination and storage of cork-oak acorns. Cork-oak acorns are very similar to acorns of all other species of the white oak group, but they do not exhibit the dormancy phenomenon and they germinate as soon as they fall from the trees in the autumn. The acorns gathered in the fall of 1942 in different localities of California usually varied in weight from 90 to 150 acorns to the pound, although occasionally the acorns were much larger or much smaller. The moisture content of California cork-oak acorns is about 75 to 80 percent of their dry weight; when their moisture is decreased to 30 or 35 percent the acorns lose their capacity to germinate. In order to assure high viability of stored cork-oak acorns, their moisture content should be maintained at a high level.

Germination of cork-oak acorns has certain peculiarities. The initial stages of germination are accompanied by extensive growth of the hypocotyl, which reaches an underground length of 10 to 15 cm. Many buds are formed on the hypocotyl and these are capable of sprouting when the plumule is dead or when the main shoot has been removed. This capacity of developing hypocotyl buds has practical importance in assuring the survival of cork-oak transplants when, for instance, the shoot is clipped off by rodents.

Storage of cork-oak acorns at room temperature, either in bulk or in containers, is not recommended. Viability of the acorns can be maintained in cold storage (32° - 40° F.) for 10 weeks if they are packed in large burlap sacks or for 10 months, possibly longer, if they are mixed with dry sand in airtight 5 gallon cans. Stratification in moist peat is not advisable.

The effect of growth-inhibiting substances on germination and development of cork-oak acorns was studied. The experiments seem to indicate that treatment with naphthaleneacetic acid and its derivatives for a short period of time might retard the germination of cork oak acorns. Further experiments are needed in this direction.

Harvested cork-oak acorns in 100-pound burlap sacks can be shipped by truck to place of planting in California. Shipping in burlap sacks by express or freight is not recommended. Small lots can be sent in airtight containers by mail or express. When shipped in 1 quart jars the acorns retain their original viability for at least 2 weeks.

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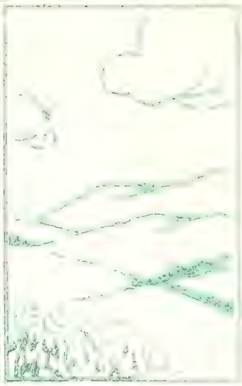

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HOW TO SOW MUSTARD
IN BURNED WATERSHEDS OF SOUTHERN CALIFORNIA[1]

By

Clark H. Gleason, Forester

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[1] Originally titled "Directions for Sowing Mustard for Erosion Control in Burned Areas of Southern California."

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INTRODUCTION

After the chaparral cover of the mountain watersheds in southern California is burned, damage is usually done during winter storms by increased runoff and erosion debris from the denuded area. The damage is done not only to the works of man, but to the watershed itself. Improvements that most often suffer tangible damage include water storage and diversion structures; roads, trails, railroads, and public utility lines; agricultural land; campgrounds, cabins, homes, and even whole communities. Other tangible losses are incurred through the wastage of flood water by-passed to the ocean because of its high silt content -- water that would normally have been used directly or conserved in underground basins through water-spreading grounds.

Damage is also done to other values, intangible as to dollar valuation but no less real. This includes such items as the deterioration of soil productivity through accelerated erosion in the burned area, interruption of communications, and the loss of human life.

Many years are required, under natural conditions, for regeneration of the plant cover and the restoration of normal runoff and erosion conditions. Many native chaparral shrubs sprout from their burned stumps or grow from seed soon after the fire, but through several growing seasons the soil between the shrub stumps may remain bare or develop only a thin cover of herbs and grasses.

For a "first aid" treatment to help recover and stabilize the bare soil, promote infiltration, reduce runoff and erosion, and thus lessen the damage from burned-area floods, some plant is needed that will make a quick growth thoughout the area in which it is sown. The seed must be available in large quantities on short notice at low cost. The seed must sprout quickly and survive when broadcast without seedbed preparation or covering of the seed after sowing. The seedlings must withstand the heat, cold, and drought conditions of the site. The sown crop should produce dense cover and durable litter; it should reproduce itself for two or three years after sowing; and it should yield to the native cover when the native cover has regrown. Of many selected plants tested by the Forest Service for this use, common mustard has been found best in meeting these requirements in southern California.

Mustard sowing alone, however, can not wholly prevent damage from burned-area runoff and erosion; in fact, no plant cover can be established completely and quickly enough to afford the degree of soil stabilization that was exerted by the native vegetation before the fire. For full flood protection other preventive measures are required.

These measures may include the installation of debris basins at canyon mouths; check dams or other structures in stream channels; provision for better drainage along mountain roads; and the stabilization of road overcast and fill slopes. In some places the giving of a flood-hazard warning may allow occupants of an endangered area to remove or otherwise protect improvements against damage. The detailed discussion of such measures is beyond the scope of this publication.

This revision of Research Note 37 has been written to help answer many requests for information on how to sow mustard received since the original Note was issued. Since that time, too, experience with airplane sowing has broadened, and several sowing jobs have been done by helicopter. Information on use of the helicopter has been included in the present revision, which discusses the essentials of how to plan a mustard sowing job, how to conduct it, and how to judge its success. These three parts sum up the information needed for a complete job, thoroughly planned and fully recorded. On jobs involving only a few acres or those in which it is not desired to maintain a complete record of the work and its results, only applicable parts of the instructions need to be used. For agencies desiring to keep formal records of the work and its results, samples of the forms used by the Forest Service are available on request.

PLANNING THE JOB

Mustard seed needs only to be broadcast in the burned area. Because the seed germinates and grows readily in loose and ashy soil, no preparation of the ground in advance of sowing nor covering of the seed after sowing is required. This simplifies the job, both in planning the work and in doing the actual sowing.

The chief points in planning the sowing of a burn are: the sowing method to use, where and when to sow, and the seed requirements. Depending on the size and location of the job, such details as clearances from property owners or from agricultural agents, cooperative work, and release of news stories, may also require attention.

Sowing Methods; Rates and Costs

Mustard seed can be broadcast either by hand or by aircraft. It must be sown by hand when the most careful distribution of seed is required by a complicated pattern of land ownership. Hand sowing may also be required in isolated burns up to perhaps 500 acres in extent, which are so small that aircraft operators would not wish to bid on the job unless it could be done in connection with some nearby larger project. Or it may be done when ample manpower is available but there are no funds for aircraft hire. Sometimes, when seed and hand labor are immediately available, the sowing might be started by hand in order to get critical parts of the burn sown while arrangements are being made for aircraft service to finish the job.

Sowing by aircraft, which is especially adapted to large jobs, has proved less costly and much faster than sowing by hand. It also simplifies job administration by avoiding the transporting, housing, feeding, instructing, and supervising of several of the workers necessary for hand sowing. For these reasons, sowing by aircraft is the preferable method.

Both the airplane and the helicopter have been used to sow mustard seed in burned areas. The airplane is best adapted to sowing large areas in solid blocks and of relatively gentle topography, where the speed and large pay load of the airplane make possible the fastest job performance. But the airplane can operate only from a rather sizeable landing field; it is unable to hug the ground in broken terrain; and its average distance above ground while sowing must be great enough to allow space for maneuvering at high speed. These characteristics, coupled with inherently fast flight and restricted view of the ground from the cockpit, require the use of ground flagmen to guide the airplane pilot and insure good seed distribution. Moreover, its flight characteristics make airplane operation hazardous in the rugged mountains where mustard frequently must be sown.

The helicopter has demonstrated its ability to fly very close to the ground, practically following the contour in canyons too deep, narrow, and tortuous for the airplane. The helicopter used to date had a pay-load capacity only $\frac{1}{4}$ to $\frac{1}{2}$ that of airplanes customarily used for such work, but it could land at convenient points in the burned area and take on more seed without loss of time. In fact, the frequent landings made the job easier by maintaining close personal contact between the pilot and the ground workers. The slow flying speed that is practicable with the helicopter was found to be a great advantage in mustard sowing. Coupled with the ability to fly close to the ground and excellent visibility from the pilot's seat, slow speed made possible good seed distribution without ground flagmen to guide the pilot. Moreover, the helicopter was judged to have a high safety factor for sowing mustard in rugged terrain; its slow flying speed lessened the chance of crashing into canyon walls, and it was able to land almost anywhere without a prepared landing field.

Sowing burned areas by aircraft is 10 to 30 times as fast as sowing by hand (table 1). In comparing the figures in table 1, it should be borne in mind that present data on the helicopter are drawn from the first use of this aircraft for mustard sowing, operating in some of the most rugged topography in southern California. On future jobs, improved seed loading techniques and better organization may increase the sowing rate for the helicopter.

Table 1.- Comparative rates of sowing mustard by airplane, by helicopter, and by hand.

Burned area, national forest, and year of sowing	Method of sowing	Area sown	Sowing time	Sowing rate
		Acres	Hours	Acres per hour
San Luis Rey burn, Cleveland, 1947	Airplane	1,000	3.17	315
Big Tujunga burn, Angeles, 1947	Helicopter	960	7.30	130
Indian Canyon burn, Los Padres, 1934	Hand-broadcast	2,700	1/ 240.0	2/ 11

1/ A crew of 20 sowers required 30 eight-hour days.

2/ Acres per hour covered by 20-man crew.

As of December 1947, the cost of sowing mustard in burned watersheds of southern California has been estimated at approximately $1.80 an acre by aircraft, and $3.95 an acre by hand (table 2). These costs of mustard sowing are the highest on record.

The 1947 estimates are from actual bids on a 1,000-acre sowing job. For this job, three helicopter bids were received; they ranged from $0.78 to $1.32 per acre and averaged $1.08 per acre. Eight airplane bids ranged from $0.73 to $1.85 per acre and also averaged $1.08 per acre. The job was actually done by airplane at the contract cost of $0.73 an acre for flying. The low bids for airplane and helicopter, both submitted by operators experienced in sowing mustard, were used in making the calculations for table 2. Costs of hand labor were estimated for a sowing rate of 5 acres per man-day, requiring 10 days for a 20-man sowing crew.

Table 2.- Comparative costs of sowing mustard by airplane, by helicopter, and by hand, based on airplane sowing of San Luis Rey burn, Cleveland National Forest, in December 1947.

Item	Cost and sowing method		
	Airplane[9]	Helicopter[9]	Hand
	Dollars		
Labor	[1] 891	[2] 919	[3] 2,475
Mustard seed[4]	704	704	704
Automotive equipment rental	[5] 15	[6] 12	[7] 53
Miscellaneous equipment	9	4	32
Total	1,619	1,639	3,264
Overhead[8]	32	33	326
Total	1,651	1,672	3,590
Contingency (10 percent)	165	167	359
Total project cost	1,816	1,839	3,949
Cost per acre	1.82	1.84	3.95

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[1] Includes $727 flying contract and $155 for ground workers, plus 1 percent allowance for incidentals.

[2] Includes $785 flying bid and $125 for ground workers, plus 1 percent allowance for incidentals.

[3] Includes $2251 for hand labor and $84 for supervision, plus 6 percent allowance for incidentals.

[4] 3350 pounds of mustard seed at 1947 price of $0.21 per pound.

[5] 1 passenger automobile, 1 jeep, and 1 ½-ton pickup, 220 miles at $0.07.

[6] 1 passenger automobile, 1 jeep, and 1 ½-ton pickup, 165 miles at $0.07.

[7] 1 passenger automobile, and 1 ½-ton pickup, 350 miles at $0.07; and one 1½-ton stakeside, 200 miles at $0.14.

[8] Allowance for increased office work, such as extra payrolling and purchasing, required by the project. For hand-sowing jobs this is estimated at 10 percent of the direct costs; but on airplane and helicopter jobs the number of extra workers is so small and the job is so quickly done that an overhead allowance of only 2 percent is made.

[9] 1953 costs for this type of flying are probably 30 percent higher than in 1947.

Where to Sow Mustard

In general, a mustard cover would be beneficial in all recently burned areas in the chaparral type of southern California, especially when the potentiality exists for considerable flood and debris damage from the burn. Even though improvements are so situated that they may suffer little or no direct damage from flood waters and debris, it may still be desirable to sow mustard to hasten the establishment of protective vegetation in the burned area and lessen site deterioration. These are basic requirements of good watershed management for which mustard sowing is a relatively inexpensive aid. More specifically, the density of volunteer native plant growth, the condition of the soil, and the completeness of the burn will govern the sowing of mustard in burned areas.

Obviously, it would be undesirable to sow mustard in burned areas that had already developed an excellent cover of native herbs. Such growth might occur locally, particularly in burns of early summer within the fog belt near the ocean. By an "excellent" cover is meant herbs of the density and growth development to be expected of mustard in its first year: 5 or 6 plants per square foot, covering at least 75 percent of the soil when in the basal leaf stage, and growing to a height of 3 to 4 feet at maturity. If the native herb cover has less than this density or growth development (and experience has shown this to be the usual condition) it will usually be desirable to sow mustard.

Mustard grows best in areas of loose soil that were dominated before the fire by chaparral, sagebrush, or woodland, at elevations up to about 4500 feet above sea level In such burns the seed should be sown over all slopes, regardless of steepness, exposure, or site conditions. If several months have elapsed since the fire, and rain has fallen, the surface mantle of loose soil and ash in some places may have been washed off or compacted; nevertheless, these places should be included in the sowing, along with other small areas in which the soil surface was barren and compacted before the fire. Such compacted areas are less favorable for mustard growth, but the survival of even a few plants will improve the cover.

Mustard is not usually sown in "patchy" burns, in which the unburned area greatly exceeds the burned area. Areas in which the fire burned lightly and only scorched the chaparral, leaving some foliage and a dense stand of shrub stems, do not require sowing, nor do rocky talus slopes that have little or no soil

Mustard should not be sown in grassland, such as potreros or mountain meadows, because its introduction into such grazing areas is undesirable and the scorched sod usually gives adequate protection to the soil until the grass recovers. Nor should mustard be sown on slopes above agricultural land, particularly grain fields, in which the mustard might become a weed.

Burns that are more than 4500 feet in elevation, where winter temperatures are unfavorable for mustard growth, will usually not require sowing, although it may be desirable to sow burns in the chaparral type on warm southerly slopes up to about 5000 feet elevation.

In some burned areas sowing may be impracticable because the complex pattern of land ownership makes it impossible to obtain the consent of all the owners and get the job done before the winter rains set in. Obviously mustard may not be sown on lands whose owners object to the introduction of this plant. In summary, then:

Sow mustard

1. In recently burned areas up to about 4500 feet elevation, where native herb count less than 5 or 6 plants per square foot.

Don't sow mustard

1. Where there is already a dense cover of native herbs of growth form equal to mustard.
2. Above 4500 feet in elevation, except for southerly exposures in chaparral.
3. In "patchy" burns and areas only scorched by the fire.
4. On slopes of rock talus.
5. In potreros and mountain meadows.
6. On slopes close above agricultural land.
7. Where property owners object.

When to Sow Mustard

To have the greatest chance for success, mustard sowing should be completed before the first winter rain. In southern California the first winter storms usually come in October or November and increase in frequency, amount, and intensity of rainfall to a maximum in February. Periods of warm weather suitable for plant growth usually follow the early storms. But December and January generally bring colder weather that is unfavorable for mustard growth, together with increased expectancy of the dry, northerly gales (called "Santa Anas") that sometimes desiccate even the hardy native plant growth.

Sowing before the first rains is desirable to take advantage of the uncompacted and ashy soil surface that is most receptive to seed. Early sowing also lessens the chances of the job being interrupted by bad weather, and permits the mustard plants to get well established before cold winter weather sets in.

Cold weather retards seed germination and inhibits plant growth. In fact, freezing temperatures that occur just after the mustard seeds have sprouted are likely to kill the tender seedlings; however, mustard plants that have reached a height of about 3 inches are quite hardy and have been observed to withstand temperatures as low as 22° F. Finally, late sowing may result in stunted growth and failure to produce volunteer seed, especially if rainfall is deficient in the late winter and spring. The record of 23 mustard sowing jobs from 1932 through 1946 shows that most of the burns sown after mid-December did not develop a satisfactory first-year mustard growth. For these reasons, *all sowing should be finished by the middle of December.*

If burns occur in the months August to November, the sowing must be organized to get the seed on the ground without delay. This requires quick action in planning the job and in buying seed, and sustained sowing effort.

When fires occur during the months January to July, the burns should not be sown until the following fall. Such burns should be examined in August to determine the need for sowing, as indicated by the density of natural vegetation and the condition of the soil.

Seed Requirements

Two kinds of mustard have been found particularly suited for use in burned areas of southern California. These are the cultivated variety of black mustard, *Brassica nigra*, and Montana Trieste mustard, a variety of *Brassica juncea*. Both species have several other common names (Appendix I).

Preference is given to *Brassica nigra* for burned-area sowing, as this seed is produced in southern California and is well adapted to local climatic conditions. The use of local seed also saves delivery time and shipping costs. In years when the supply of California seed is short or unusually high in price, *Brassica juncea* from Montana or the Pacific Northwest may be substituted.

Quality

The mustard seed should be high in germination, pure, and free of noxious weeds. Small lots (up to 100 pounds) can usually be obtained from a local seed dealer. Large quantities of seed are most advantageously bought on bid from the larger seed houses. The seed specifications used by the Forest Service require minimum germination of 85 percent in 7 days, minimum purity of 97 percent, and freedom from primary and secondary noxious weeds as specified by the Agricultural Code of California. The dealer is asked to supply a notarized certificate that these specifications are met.

Offers have sometimes been received for odd lots of *Brassica nigra* or its wild variety at considerably reduced prices. Such bargain seed is usually obtained in the process of cleaning cereal grains. Either low germination or the presence of primary or secondary noxious weeds would disqualify such seed for use.

Amount of Seed to Sow

Mustard seed is sown at an average density of 20 seeds per square foot, which is equivalent to 5 pounds per acre when the seeds run 175,000 to the pound. Experience has shown that this amount of seed is required to yield 5 or 6 mature mustard plants per square foot after normal losses through failure of the seed to germinate and natural mortality among the young plants.

The number of mustard seeds per pound varies from about 150,000 to 600,000. This may not be important with only a small area to sow but with large areas it will pay to make a field calculation of the pounds of seed to be sown per acre for each lot of seed (Appendix 2). Steepness of slope has a negligible effect on the rate of sowing, and this factor may be disregarded in calculating the overall sowing rate. Where rock occupies a considerable portion of the ground surface over large areas, the sowing rate can be reduced to the amount of seed required to cover the exposed soil at the proper density.

Delivery

Mustard seed produced in southern California is usually trucked to the job by the dealer. Seed produced in more distant places is usually shipped by freight to a dealer's warehouse in southern California. From there it can be trucked to the job. Details of delivery must be worked out in advance so that the delivery point can be specified in the invitation to bid.

On aircraft sowing jobs it is best to have the seed delivered direct to the airport or operations base, if this can be designated in advance, to avoid rehauling. If the operations base can not be specified, or if there is doubt as to whether the sowing will be done by aircraft or by hand, seed can be delivered at a point that best meets the requirements for safe storage and accessibility to the job. If seed storage at some point other than the base airport is decided on, it should be kept in mind that a single airplane can sow as much as 10,000 pounds of seed in one day, and that this supply will have to be maintained at the airport to avoid delaying the job.

Examining and Storing Seed

A few sacks of inferior seed have sometimes been included in a large order, notwithstanding the rigid specifications and the requirement that the dealer furnish a certificate guaranteeing conformance with the specifications. For this reason, it is wise to examine carefully all seed upon delivery, checking its weight and appearance as indicators of quality.

Bulk mustard seed is usually sold in 100-pound sacks. If the full sacks weigh only 85 or 90 pounds, the seed viability may be low and should be tested. Good mustard seeds are well filled, not shrivelled or wrinkled, and there are few empty hulls and half-seeds. The stems and foreign seeds that are the impurities commonly found in mustard seed can be readily seen with the naked eye.

If the sacks weigh close to 100 pounds and the seed appears good, it will usually be safe to sow, in view of the dealer's guarantee of quality. But if either the germination or purity is suspect, the seed should be withheld from sowing until its quality can be determined.

If seed purchased locally proves to be of doubtful viability or purity, the dealer will usually be glad to substitute good seed without question. If inferior seed is received from a dealer at some distance from the delivery point, however, it may be desirable to send a sample to the nearest seed testing laboratory for analysis and report,[2] as the basis for claiming restitution. (For instructions in seed sampling procedure, see Appendix 3)

Until the mustard seed is actually sown, it must be protected to prevent its deterioration through exposure to dampness. For a few days' storage on the job, a tarpaulin or tent cover, with poles or brush for a floor will usually give enough protection. On hand-sowing jobs in remote back country, care should be used to locate seed caches at accessible points where adequate protection can be provided in case of a storm. For long-time storage of large quantities of seed, a dry and well-ventilated warehouse is advisable, and the seed sacks should be stacked to allow free circulation of air.

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[2] The California Seed Laboratory, of the State Department of Agriculture, at Sacramento, is fully equipped for this work. Germination and purity tests are made without charge for agencies of the State and Federal governments, and at a nominal fee for other agencies and private individuals. The services of private seed testing laboratories are also available in Berkeley and Los Angeles.

Clearances

Four types of clearances may be required from various authorities before mustard seed is sown in burned areas. These are concerned with operations on private land, weed control, certification of the aircraft and the pilot for seeding, and military restrictions on the use of aircraft.

Operations on private land require permission of the owner, both for entry on the land and for the sowing of mustard. Residents of southern California usually have no objections to entry, but they have sometimes protested the use of mustard because they remember it as a serious pest in the Mid-west, where many of them formerly lived. Such objections are usually withdrawn when it is explained that there are no extensive grain fields in southern California close to the watershed areas in which mustard is sown, and that for many years mustard has been used as a cover-crop in citrus groves throughout that part of the state.

The weed control clearance is necessary (1) to avoid the introduction of mustard into areas where it might create an agricultural weed problem, and (2) as a check against the introduction of undesirable seeds along with the mustard seed. Such a clearance is issued by the County Agricultural Commissioner, who will usually require an explanation of the nature of the mustard sowing project, and a copy of the seed specifications; he may also require a sample of each lot of seed that is to be sown. Any seed tests needed to obtain this clearance should be completed in time to avoid delaying the actual sowing of seed.

Both the aircraft and the pilot for the sowing job must be certified by the California Aeronautics Commission. Contractors based in California and regularly engaged in seeding and spraying work will already have this certification; out-of-state operators may have to obtain it.

Military clearances, such as that required to operate over restricted areas, are best provided for by making them the responsibility of the aircraft contractor when calling for bids on the job.

Cooperation and Publicity

When large areas are to be sown usually one or more public agencies, as well as private landowners, will be concerned with any plans for erosion-control treatment of a burned area. Interested parties may include the local water company, flood control districts, flood control survey groups, State and County foresters, Forest Service, Soil Conservation Service, or other

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3/ Offices of the County Agricultural Commissioners in southern California are located as follows:

Los Angeles County	808 N. Spring Street, Los Angeles 12
Orange County	1104 N. 8th Street, Santa Ana 9846 S. Harbor Blvd., Anaheim
Riverside County	Courthouse, Riverside
San Bernardino County	566 Lugo Ave., San Bernardino
San Diego County	Bldg. 2, Operations Center, Pacific Highway at Rosecrans St., San Diego 10
Santa Barbara County	Courthouse, Santa Barbara (P.O.Box 127)
Ventura County	815 Santa Barbara St., Santa Paula

Federal agencies, soil conservation districts, and organizations of farmers and stockmen. The local County Farm Advisor should also be told of the plans.[4] All such agencies should be informed of the objectives of the mustard sowing, and they may wish to cooperate in doing the work.

Experience has shown that there is need for care in giving out news stories to avoid imparting the idea that mustard alone can prevent floods. It should be made clear that mustard sowing is an emergency practice in watershed management intended to increase the plant cover in the burned area, but that other measures such as the installation of debris basins will usually be required for full protection against floods.

DOING THE JOB

Equipment, techniques, man-power requirements, and individual responsibilities vary with the sowing method. The objective of all methods, however, is to get the seed evenly distributed at the proper density and at the proper time over the areas designated for sowing. Hand-sowing proceeds slowly and requires techniques and equipment with which most workers are familiar. Sowing by aircraft, which is especially adapted to large areas, is fast, requires more elaborate equipment, and utilizes techniques with which many field men are unfamiliar. To get the proper seed distribution and avoid delays, close attention to a number of operating details is required when sowing by aircraft. Hand-sowing is here discussed first and is followed by a general description of sowing by aircraft; detailed suggestions for sowing by aircraft are given in Appendix 4.

Sowing by Hand

The size of the crew for hand-sowing jobs will be determined by the area to be sown, the urgency of completing the job, and the number of foremen available. Experience has shown that one foreman can supervise about 25 sowers.

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[4] Offices of the County Farm Advisors in southern California are:

Los Angeles County	808 N. Spring St., Los Angeles 12
Orange County	1104 W. 8th St., Santa Ana
Riverside County	Post Office Bldg., Riverside
San Bernardino County	566 Lugo Ave., San Bernardino
San Diego County	Bldg. 1, Operations Center, Pacific Highway at Rosecrans St., San Diego 10
Santa Barbara County	Federal Bldg., Santa Barbara
Ventura County	52 N. California St., Ventura

In estimating the size of crew required and the length of job a sowing rate of 5 acres per man-day has been found advisable to allow leeway for unforeseen delays. Actually, however, ground crews have averaged about 7 acres per man day in moderately rough country while a maximum of 10 acres per man day has been attained. The acreage sown per man-day will naturally depend on the amount of travel time and the number of hours worked, the 7-acre figure allowing 1 hour in travel during an 8-hour day.

For ground work it has been found best to divide the burned area into component drainage units, which may range in size from 25 acres to perhaps 400 acres. Small crews of 2 to 5 men and a strawboss are given full responsibility for sowing these drainage units. In sowing, the men walk back and forth across the slope on contour, starting at the top of the slope and working downward, broadcasting swaths about 20 feet wide. Some precipitous slopes too steep to climb over contain benches of erosible soil on which a protective cover of mustard is needed. These slopes can generally be sown by throwing handfuls of seed from the top and sides.

Special treatment to make the seed stay on the slope instead of rolling to the bottom can be given on loose sliding cones of soil and on road overcast slopes. This treatment consists of having the men work across the slopes on contour lines 3 to 4 feet apart slope-distance, taking short steps and sowing as they go. By this method, most of the mustard seed will ultimately lodge in the men's footprints. To avoid excessive density of the mustard plants, the quantity of seed sown should be reduced to about 1 pound per slope-acre.

While the sowers are at work the foreman should make spot checks of seed distribution by counting the number of seeds on the ground in selected areas to be sure that the density is about 20 seeds per square foot. A daily check should be made of the acreage sown and the amount of seed used following the general method outlined in the detailed suggestions for aircraft sowing (Appendix 4).

Transportation of the seed to the sowing point is governed by conditions on the job. In remote areas a few pack animals to carry supplies of seed to points convenient for the sowers may facilitate the work. Generally, however, each man carries his day's seed supply with him. Where there are sufficient roads, time and effort will usually be saved by having the sowers hauled to the top of the mountain by truck in the morning and picked up at its foot after the day's work.

The equipment needed for each sower includes a knapsack to carry a day's supply of seed. From 25 to 50 pounds may be carried, depending on the topography and distance of the sowing area from the base camp or truck. For measurement each sower also carries a one-gallon can (No. 10 size), which holds approximately 5 pounds of mustard seed, enough for one acre. The seed is broadcast by hand because mechanical seeders have been found impractical for use on the steep slopes usually encountered in burned areas.

Sowing by Aircraft

Whether mustard seed is sown by airplane or by helicopter,[5] for the safety of the pilot and for uniform seed distribution, aircraft sowing should be done in calm weather. As the winter season approaches, good flying weather may be limited to a few hours each morning, from daybreak to about 10 a.m. Sometimes conditions again become suitable for flying in the late afternoon and evening. If it is urgent that a job be completed before an impending storm, the pilot may be willing to fly in less calm weather or for longer hours. It is important to remember, however, that the pilot should be free at all times to decide when he will fly and how he will cover the area. He alone knows what he and his aircraft can do.

With either type of aircraft, the basic problems involve broadcasting the seed with maximum uniformity over the burned area, and doing the job as rapidly as possible commensurate with safety and proper distribution of the seed. The equipment, landing-field requirements, flying techniques, and man-power needed differ according to the type of aircraft used. (Specifications for aircraft service are given in Appendix 5.)

Equipment

Open cockpit or cabin type airplanes which have a capacity from about 500 to 1500 pounds of seed are customarily used to sow mustard. Such planes are in regular use for crop-dusting and rice-sowing operations and require only minor changes to adapt them for mustard sowing. Special equipment required for sowing includes a seed hopper built into the plane, gates for controlling the flow of seed from the hopper, and a Venturi flume or other type of spreader mounted beneath the fuselage to spread the seed evenly. Seed flows by gravity from the hopper into the spreader, where it is swept away by wind from the propeller. The flow of seed is controlled by one or two gates to start and stop the flow, and to control its rate. The gates are operated from the pilot's cockpit. The concentration of seed sown is governed by both the gate setting and the speed of flight.

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[5] Mustard seed was first sown in burned areas by airplane on Los Padres National Forest in 1932 and 1934. The next airplane sowing was done on the San Bernardino National Forest in 1940 and 1941, followed by additional work on the Cleveland, San Bernardino, and Angeles National Forests in 1943, 1947, and 1948. The helicopter was first used to sow mustard on the Angeles National Forest in October 1947.

A two-place helicopter with open cockpit was used for the mustard sowing.[6] The pay load of this helicopter with standard equipment was 400 pounds maximum. As altitude increased, however, it was necessary to reduce the pay load in order to improve flying performance, especially on hot days. The maximum working altitude at which this model helicopter could take off with load, hover, and land was approximately 5500 feet. Once aloft, however, the machine could continue in flight with a load at altitudes of over 10,000 feet, so long as sufficient air speed was maintained. On the Big Tujunga burn of 1947, sowing was done up to an altitude of 4000 feet, carrying as much as 330 pounds of seed. The pilot reported that the aircraft handled satisfactorily above 5400 feet with from 180 to 220 pounds of seed in the hoppers.

The helicopter was equipped with twin hoppers and tube assemblies for carrying and spreading the seed. As in an airplane, the flow of seed was controlled by release and metering gates in the bottom of the hoppers, and the rate of sowing depended both on the setting of the metering gate and the speed of flight.

Landing-field Requirements

For safe operation, the airplanes used for mustard sowing require a fairly smooth and level landing field at least one-half mile long. Other conditions being equal, a landing field at low elevation is preferable to one at high elevation because of the greater density of the air at low altitudes and the resultant increase in "lift" for taking off with a load of seed.

The helicopter, by contrast, can operate from any plot of ground that is free of obstructions for a distance great enough to clear the rotors, i.e., a minimum diameter of about 50 feet for the helicopter used in 1947.[6] The operating location, or helispot, for such sowing jobs should be not more than 3500 feet above sea level. As with airplanes, lower elevations are preferred for the operations base, except that in some cases a ridge top might be better than an adjacent canyon bottom because of the increased maneuvering room and benefit of increased "lift" from the wind. Location of the operations base for a helicopter must be determined by the pilot.

Flying Techniques

Best sowing results with the airplane have been obtained by flying not more than 300 feet above the ground, at a speed of about 90 m.p.h. Under these conditions the airplane most recently used sowed a swath 80 feet wide at the desired average density of 20 seeds per square foot. Cross-sowing the burn in strips at right angles to improve seed distribution has been found unnecessary.

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[6] The helicopter was a Bell agricultural model 47B3; the later model 47D is similar.

Because of the airplane's fast flight and the necessity for making wide turns, it is advantageous to divide the burned area into rather large units that can be covered by a series of long, parallel, straight swaths at a safe distance above terrain, with a minimum of turns. Ground flagmen working in the sowing area and markers along its boundaries are essential ~~usually needed~~ to help the pilot cover the area completely without skipping or excessive swath overlapping.

With the helicopter, the best sowing results were obtained by flying about 50 feet above the ground, at a speed of 30 m.p.h. The width of swath sown was 60 feet and the seed density averaged 20 seeds per square foot with highly uniform distribution.

The helicopter's flight characteristics made it possible to sow the burned area by small watershed units, up to about 250 acres in extent, thereby concentrating the ground personnel in a small area. Flight tests showed that flying on contour and working downward from the head of a drainage was the easiest method of covering the area, owing to lessened power requirements. It was also found that the pilot had an unrestricted view forward, downward, and to the sides. Consequently, he could fly by ground landmarks, such as rocks and burned shrubs, and obtain uniform seed distribution without the aid of flagmen. Boundary markers were dispensed with by having the sowing foreman make a flight over the area with the pilot just before it was sown, to point out the boundaries and give any special instructions needed. All these techniques combined to make the results of sowing by helicopter approach a degree of selectivity and uniformity possible heretofore only through hand-sowing.

Man-power Requirements

An effective crew on an aircraft sowing job of 1,000 acres should include a foreman, two flagmen (if the sowing is done by airplane), two ground checkers to check seed distribution in the burned area, a truck driver, and one or two men at the operations base to help load the aircraft. These men are needed in addition to the pilots and mechanics who operate and service the aircraft.

In burned areas larger than 1,000 acres the number of flagmen required will be governed by the size, shape, and topography of the sowing area; at least two will be needed, and more may be desired by the pilot. It will also be desirable to have more ground checkers, so that at least 10 percent of the area can be sampled.

JUDGING THE SUCCESS OF THE JOB

The success of a mustard sowing project must be judged in terms of the mustard crop itself. The criteria to use are the uniformity and density of the mustard cover, and the height of stand obtained.

Good first-year mustard stands in the past have been evenly distributed and have averaged 200,000 mature plants per acre, with an average height of 3 to 4 feet, in more than 90 percent of the area designated for sowing. The litter produced by such a stand has been measured at $2\frac{1}{4}$ tons per acre (oven-dry weight). This density and uniformity of stand should be taken as the desirable objective. However, mustard sowing projects have been considered satisfactory if the first-year stand averaged 25,000 plants per acre in 75 percent of the area designated for sowing.

A dense second-year mustard growth usually develops from volunteer seed, even though the first-year mustard stand may have been sparse. In such a case, the project might become highly successful in the second year. Thus, "success" should be judged in terms of mustard growth and distribution in both the first and second years after sowing.

In experience to date, the most serious cause of unsatisfactory mustard growth has been careless sowing, this factor having proved even more critical than unfavorable growth conditions. Obviously, mustard can not be expected to grow where the seed is not sown. In areas where good seed was sown, some mustard has always grown to maturity; never has the entire crop been lost. For success, careful sowing to insure complete coverage of the area with seed is of the utmost importance.

Mustard Growth Examinations

Information on the growth and distribution of mustard is best obtained through field examinations made when the mustard is in full flower, usually in April or May. At this time the mustard can be identified at a distance by flower color. By counting the plants in a few sample stands of different color and appearance, a man can quickly develop judgment that will enable him to estimate the number of plants per milacre,[7] much as a farmer judges the yield of his crops from appearance of the fields. Outlining the areas of different densities on a map will record their location and will permit estimating the acreage of areas successfully sown. Such examinations are usually made the first and second years after the mustard is sown.

In a first-year examination, experience has shown that four density classes are convenient for use:

Dense: more than 100 plants per milacre
Medium: approximately 26-100 plants per milacre
Sparse: 25 or less plants per milacre
Failed: areas with no mustard

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[7] A milacre contains 43.56 square feet, 1/1000th of an acre. It may be either 6.6 feet square, or 3.3 feet wide by 13.2 feet long.

The density of 25 plants per milacre is an important division point, as this is the approximate number of plants usually required to make a blanket flower color that is readily distinguishable at a distance. To account for the entire burned area, the examiner should also record areas missed in sowing, unburned "islands," precipitous and rocky areas, and cultivated and residential areas.

In a second-year examination it may be desirable to recognize additional density classes because of the great increase in plant numbers. The limits of such classes must be decided on the ground by the examiner, as they will depend on the number and development of plants growing, and on the degree of detail desired in the survey.

Observation Plots and Photographs

If it is desired to determine the causes of sparse mustard growth or of its failure to grow in local areas, close observation will be required throughout the growing season. Drouth, desiccating winds, and extreme cold may take their toll of the tender mustard seedlings, or in some cases the mustard may get a good start but fail to mature and produce seed. Observations of the effects of such adverse environmental factors are best made in small plots installed at the time mustard is sown, and checked at frequent intervals.

Paired milacre plots, one sown and the other not sown, afford the best means of studying the growth of mustard and comparing it with native plants in sown and unsown areas. A good plot size is 3.3 feet wide by 13.2 feet long (one milacre), and it is preferable to have the long dimension up-and-down the slope, that is, parallel to the direction of runoff. These may be slope measurements without correction to horizontal distance as would be desirable for larger plots. One plot of each pair should be carefully sown by hand, making sure to sow the same number of seeds per square foot that are sown elsewhere in the burn. The second plot of each pair is left unsown

As many pairs of plots may be used as are needed to represent the different conditions of soil, aspect, steepness, and altitude, a single pair usually being enough to check each site condition for ordinary observations. The plots of each pair should be spaced at least 25 feet apart to decrease the chances of mustard migration into the unsown plot, especially if observations are to be carried into the second year. Statistical design of the plot installations is not required for these studies because the plots are used to help interpret results of the mustard growth examination in the burned area as a whole, and not as statistical samples of the burn.

Good photographs, repeated at intervals from the same camera stations, will also help, by providing a record of the burned area before sowing and the subsequent growth of mustard. Photos in natural color are useful in showing differences in the soil and plant cover, but black-and-white pictures are the most practical for general use.

APPENDIX I

SPECIFICATIONS FOR THE PURCHASE OF MUSTARD SEED

Rather precise specifications are required to obtain the kind of mustard seed desired for burned area sowing, because of the lack of standardization among common and trade names for the various species and varieties of mustard. The following specifications prepared by the California Forest and Range Experiment Station, assisted by the Regional Fiscal Agent, have been used by the Forest Service in purchasing mustard seed during the last several years. The paragraphs shown constitute only the technical portions of the bid form. Details of quantity, delivery point, adherence to special contractual conditions, etc., are to be supplied by the purchasing agent according to customary procurement procedure.

It is important that samples be drawn immediately on receipt of the seed (see General Specification 5) in order to avoid delay in certifying claims for payment. The seed samples should then be forwarded promptly to the California Seed Laboratory for testing in accordance with Gen. Spec. 5. The penalty clause in Gen. Spec. 6 is included to allow compensation for any seed that might fall below the minimum requirement in germination. The inclusion of such a clause permits sowing the seed immediately on delivery, avoiding delay in starting the sowing job.

Specifications for the two suitable species of mustard are given in paragraphs A and B. In years of normal seed supplies the bid would customarily be worded to invite quotations on only the less costly of the two species of seed. In this case either Specification A or Specification B would be deleted, depending on which species is more readily available or cheaper.

SPECIFICATION A

Mustard seed of the variety known by the common name of Black mustard and known in botanical science as *Brassica nigra*. This seed is sometimes called "California Trieste (cultivated)", "Red," "Trieste," "Trieste Brown," or "Trieste Red," but the variety desired in this transaction is the brown-seeded kind grown largely in the vicinity of Lompoc, California, and must be certified to have been grown in California.

SPECIFICATION B

Mustard seed of the variety known by the common names of "Montana Trieste," "India" or "Indian" mustard, and known in botanical science as *Brassica juncea*. This is a brown-seeded variety, the seeds of which resemble but run slightly larger than those of *Brassica nigra*, and which is produced under cultivation in Montana, Washington, and Oregon. A statement certifying the source of the seed shall be provided.

GENERAL SPECIFICATIONS

1. No bid on any variety of yellow-seeded mustard, either domestic or imported, will be accepted, even though these be designated as varieties of the botanical species Brassica juncea.

2. All seed must conform to the provisions of the California Seed Law and quarantine inspection regulations, particularly as to quality, labeling, and conditions of shipment.

3. All seed must be of the . (insert current year) . crop, of a minimum purity of ninety-seven percent (97%), and must contain no primary or secondary noxious-weed seeds as designated by the California State Department of Agriculture.

4. Mustard seed must yield a minimum germination of eighty-five percent (85%) in seven (7) days, as determined by standard test of the California State Department of Agriculture, on composite samples drawn in accordance with Rules and Regulations under the Federal Seed Act (see pages 11 and 31, Service and Regulatory Announcements No. 156, Production and Marketing Administration, February 1946).

5. On delivery of the seed, samples shall be drawn by a Government officer who will send them to the California Seed Laboratory at Sacramento, California, for the standard germination and purity tests. If he wishes, the successful bidder may have a representative present at the time these samples are extracted. The Seed Laboratory will report to the Government and will mail a copy of the report directly to the successful bidder.

6. Should the germinability of the samples, chosen as outlined in the preceding paragraphs, from the seed submitted by the successful bidder, fall below the stipulated minimum percentage, then the payment for the seed will be discounted by one-tenth (1/10) of one cent per pound for each percent below eighty-five (85) in seven (7) days, as shown by the tests of the California Seed Laboratory. (Such penalty, if applied e.g. to a hypothetical total purchase of 1000 pounds, would amount to $1.00 for each percent deficiency.)

7. Successful bidder must present with invoice a notarized certificate to the effect that the seed furnished is of at least as high quality in all respects as the minimum requirements noted above.

8. Delivery shall be made within seven (7) days after notice of award is received. NOTICE OF AWARD WILL BE GIVEN SUCCESSFUL BIDDER BY TELEPHONE in order to expedite delivery, and later confirmed in writing. If delivery time herein specified cannot be complied with by bidder, he should specify minimum time required for delivery; otherwise, the terms here stated will be mandatory upon successful bidder.

APPENDIX 2

METHOD OF CALCULATING NUMBER OF SEEDS PER POUND AND WEIGHT OF MUSTARD SEED TO BE SOWN PER ACRE

Mustard seed sown in burned areas to date has ranged from approximately 147,000 seeds per pound of *Brassica juncea* grown in Montana to 302,000 seeds per pound of *B. nigra* grown in California. At 5 pounds per acre, this would amount to 17 seeds per square foot and 35 seeds per square foot respectively. It is therefore desirable to determine the number of seeds per pound for each lot of seed delivered, and to calculate the weight of seed to be sown per acre in order to attain the desired sowing density of 20 seeds per square foot. This determination is made as follows:

1. Weigh out 60 grains of mustard seed.[8] (60 grains = 1 dram Apoth. = 0.125 ounce Apoth. = 0.137 ounce Avoir. = 3.888 grams Metric = 0.008571 pounds Avoir.) Local druggists are usually glad to cooperate by weighing the seed.

2. Count the number of seeds in the 60-grain sample. Then, assuming for this calculation that there are 1575 seeds in the sample,

3. $\frac{1575}{.008571}$ = 183,759 seeds per pound (Avoir.)

4. 20 seeds per sq. ft. x 43,560 sq. ft. per acre = 871,200 seeds desired per acre.

5. $\frac{871,200}{183,759}$ = 4.74 lbs. (Avoir.) seed required per acre.

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[8] The grain is common to Avoirdupois, Troy, and Apothecaries' systems.

APPENDIX 3

INSTRUCTIONS FOR SAMPLING MUSTARD SEED

In sampling any seed it is important to take the samples so that they will be truly representative of the body of seed sampled. The sampling procedure under the Federal Seed Act should be followed.[9/] Portions of this procedure that are applicable to mustard seed are briefed as follows:

1. In order to get a representative sample, equal portions shall be taken from evenly distributed parts of the quantity of seed to be sampled; access shall be had to all parts of that quantity.

2. A probe, or trier, long enough to sample all portions of the bag shall be used.

3. As the seed is sampled, each portion shall be examined; if there appears to be a lack of uniformity the portions shall not be combined, but shall be retained as separate samples to determine such lack of uniformity as may exist.

4. When the portions appear to be uniform, they shall be combined to form a composite sample.

5. In quantities of 5 bags or less each bag shall be sampled.

6. In quantities of more than 5 bags, at least every fifth bag but not less than 5 bags shall be sampled.

7. When a shipment consists of more than 200 bags, a separate composite sample shall be taken for each 200 bags or portion thereof.

8. Samples shall be drawn from unopened bags except where the identity of the seed has been preserved.

9. For mustard seed, the minimum weight of sample to be submitted is 5 ounces.

9/ USDA Rules and Regulations Under the Federal Seed Act, Production and Marketing Administration, Service and Regulatory Announcements No. 156, February 1946, pages 11 and 31.

Each sample should be plainly marked with the following data:

Species
Name of burn where seed will be sown
Dealer's name
Dealer's lot number
Sample number
Where sampled
Date sampled
Name of person who did the sampling

The probe is a conical metal tube with tapered point that can be inserted between the meshes of the sacking to allow sampling the seed without opening the sack. When enough seed has been drawn, the probe is pulled out and the hole is closed by pushing the meshes back together. Such a tool can usually be obtained from commercial seed dealers.

If a regular seed probe is not obtainable, an ordinary glass tube can be used. It should have a bore of about 3/16 inch, should be 10 to 12 inches long, and should have the ends fused to dull the sharp, cutting edges. The cylindrical bore of such a tube is a drawback, but seed can be made to run through it satisfactorily if the tube is inserted upward into the sack and then withdrawn with push-pull motions. A glass tube is better than a cylindrical metal one because the operator can see the cause of any stoppage in seed flow. Care should be used to avoid breaking the tube and cutting the operator's hand

The best containers for mustard seed samples are 5-pound cloth sugar sacks. Ordinary letter envelopes are not satisfactory. Paper bags can be used provided three bags are used for each sample, placing one bag inside another to give a triple thickness of paper around the sample. Each sample should be securely closed to avoid leakage and mixing of the seed, and labelled with full identification data.

APPENDIX 4

DETAILED SUGGESTIONS FOR SOWING BY AIRCRAFT

In the conduct of aircraft sowing jobs, certain procedures have been found superior for getting the job done with efficiency. The following suggestions, based on Forest Service experience describe the assignment of responsibilities and list the equipment needed for certain workers. They also tell how to adjust the rate of sowing and how to mark the sowing area boundaries, and the methods found best for communication between ground crews and pilots.

Responsibilities

The foreman is responsible for the planning and execution of the work, and for certifying its satisfactory completion. He designates the areas to be sown and supervises their marking. He assists the pilot in setting up an operations base and works closely with the pilot in planning and conducting the job. He determines the number of seeds per pound, calculates the weight of seed to be sown per acre (Appendix 2), and helps the pilot make preliminary adjustment of the seed release mechanism. The foreman supervises communications, and the work of flagmen and ground checkers. He is also responsible for the maintenance of an adequate supply of seed at the operations base, and he keeps track of seed use and acreage sown to guard against running out of seed before the job is done.

Efficient and conscientious flagmen are essential. They work methodically through the burn by prearranged plan, to mark the center of each sowing swath. By appropriate signals they advise the pilot of changes in sowing rate or line of flight required to obtain the proper density and distribution of seed. As time permits between sowing flights, they make counts of the seed sown to supplement the information obtained by the ground checkers. On very large burns it is helpful to have the flagmen plot on their maps the area sown each day, for report to the job foreman.

It is important that flagmen be on location before the first sowing flight of the day and not leave the job until they are signalled to come in. For example, it may have been planned to start sowing at daybreak, but at 10.00 a.m. the plane has not appeared, and the wind has started to rise. The flagman concludes that sowing has been called off, and he leaves his post. However, it might have been not the local wind but some trouble at the airport that caused the delay. Half an hour later the trouble has been corrected, the pilot makes his first flight, and finds no flagman to guide him.

The following equipment for each flagman should be assembled before sowing is begun:

- 1 bamboo pole, very sturdy, 8 feet long
- 1 piece white muslin 3 x 5 feet, attached as flag to bamboo pole
- 1 piece white muslin 3 x 5 feet, with center hole large enough to go over man's head. This is worn like a poncho to make the flagman more readily visible to the pilot.
- 1 wire frame 12 inches square. This is used in counting the seed sown and may be carried over the arm or around the neck when not in use.
- 1 knapsack
- 1 notebook
- 1 pencil
- 1 topographic map showing boundaries of burn and sowing areas
- 1 copy of signals to be used between flagman and pilot

Ground observers, or "checkers," are needed to determine the average density at which seed is being sown within each swath, and to make sure that the swaths meet or overlap to avoid missed areas. In doing this, the checker walks straight across a sown area, and counts the mustard seeds in square foot sample areas. Such counts are made at regular intervals of from 10 to 50 feet, depending on the length of transect and size of the area to be sampled. The sample areas are chosen by dropping a frame of No. 9 telephone wire, 1 foot square, on the ground at random at predetermined intervals.

In checking seed distribution, the steepness of slope at the counting frame must be considered. Perfect distribution of the mustard seed on level ground should give an average of 20 seeds per square foot, with a range of about 10 to 30 seeds per square foot. The desired 20 seeds per square foot is calculated on a horizontal basis. Because the projected area of a one-foot square frame lying on a 100 percent slope is 29 percent less than when the frame is lying on level ground, a count of only 14 seeds within the frame on such steep slopes would still represent correct sowing density.

A ground checker usually works within shouting distance of a flagman, so that the results of his counts can be communicated immediately to the pilot by flag signal if it is found desirable to change the rate of sowing.

The truck driver hauls seed to the operations base, assists in loading the aircraft, operates the airport radio, and keeps a record of the amount of seed sown and the quantity remaining on hand. Each night he reports the seed data to the foreman for use in checking overall seed distribution.

It is customary for the agency in charge of sowing to assist the pilot in obtaining local cooperation in the use of flying fields, clearance for operating in military restricted areas, and in other problems of this nature. In practice, it has also been found best for the sowing agency to store the seed prior to sowing, deliver it to the operations base, and assist as needed in loading it into the aircraft.

Adjustments for Desired Sowing Rate

Before any sowing is done it is necessary to determine the proper setting for the seed metering gate to give the correct rate of flow with the seed to be sown. It is also necessary to determine the optimum height that the aircraft should fly above the ground in order to sow the maximum width of swath. And finally, the optimum flight speed should be determined. These three factors affect the concentration and distribution of the seed, and they vary with different seeds. The determinations are made in ground and flight tests that normally require 3 or 4 hours

If the pilot has sowed mustard with the same aircraft and seed-release mechanism (hopper, gates, and Venturi flume) he will know the approximate gate settings required to obtain the desired sowing density, and can proceed immediately to the final adjustments in flight.

If the pilot has not had experience with mustard seed in that particular aircraft, an initial test of the seed-flow rate should be made on the ground to determine the approximate setting for the release gate. This setting should then be checked in flight. The ground test is made in two steps:

1. Preliminary calculation

   a. Known: $\frac{43560 \text{ square feet per acre}}{5280 \text{ feet per mile}} = 8.25$ feet, width of swath required to sow 1 acre per mile of flight

   b. Assume: 100 feet = width of swath sown

   c. Then: $\frac{100}{8.25} = 12.12$ acres sown per mile of flight

   d. Known: This lot of seed is to be sown at the rate of 4.74 pounds per acre (Appendix 2)

   e. Then: $4.74 \times 12.12 = 57.45$ pounds of seed to be sown per mile of flight

   f. Known: At 90 miles per hour it takes 40 seconds to go 1 mile

   g. Then: In 40 seconds 57.45 pounds of seed should be released.

2. Seed flow test

   a. Put 29 pounds of mustard seed into the hopper

   b. Open the seed-release gate and let seed flow for 20 seconds, while operating the seed agitator at flying speed

   c. If the metering gate is correctly set, the 29 pounds of seed should pass from the hopper into the Venturi flume in 20 seconds; adjust the gate opening and repeat the test until this approximate rate is attained.

In flight, the rate of seed flow may be changed by vibration or other factors. For this reason, a test must be made while flying to determine the final setting for the metering gate, and to determine the optimum height above ground and speed at which sowing should be done.

The flight test should preferably be made over level or gentle slopes within the area to be sown. But if the sowing area is too remote to permit ready access by the ground checking crew, or if its terrain is too rough, an alternate site must be used.

Alternate sites used to date for the flight test have included a pier extending into the ocean a sandy beach and airplane landing fields. Testing at the landing field is most advantageous when sowing by airplane because the pilot can land between flights and observe the results of each test. But care must be used not to broadcast mustard where it might establish itself as an undesirable weed, or in areas from which it might spread to become a nuisance. When such tests are made over an unsurfaced landing field and the seeds germinate and grow, the agency in charge of sowing should accept responsibility for cutting or otherwise destroying the young mustard plants before they become tall enough to constitute a hazard on the runways.

Close observation and counting of the mustard seeds are required to determine the width of swath sown and the number of seeds per square foot within the swath. First, lay on the ground, at 10-foot intervals across the airplane's line of flight, some material that will catch and hold the seeds. Then have the airplane make a sowing flight over the catchment material. Finally, count the number of seeds sown per square foot, and measure the width of swath covered

For the counting, seed can be caught on long strips of burlap, one-foot squares of cardboard coated with heavy grease, sticky fly-paper, or even a cleanly-swept path in the burned area. The easiest catchment surface to use, however, has been found to be ordinary wax paper coated with fresh varnish or paint.

The pieces of wax paper are cut about 1 foot square and are anchored to the ground at 10-foot intervals for a distance of 150 feet on a line perpendicular to the airplane's line of flight. The papers are then varnished, the sowing flight is made, and the number of seeds per square foot on each paper is determined and recorded. New papers can be quickly placed and varnished for succeeding test flights as needed. Large nails are handy for pegging the corners of each paper to the ground. If the tests are made on the concrete apron at an airport, the papers can be "stuck" down by wetting the concrete with water.

Test flights should be continued with adjustment of the seed-metering gate, the height of the aircraft above ground, and the flying speed until an average sowing density of 20 seeds per square foot, with a range of approximately 10 to 30 seeds per square foot, and a uniform width of swath are attained. The tests should be made in still air because a breeze of even 5 m.p.h. may cause uneven seed distribution and drift.

Marking Boundaries of the Sowing Area

All boundary marking should be completed by the sowing agency before arrival of the airplane. Materials for the markers should be of light color, and durable enough to withstand heavy rain and wind. An inexpensive grade of white muslin is best, but several thicknesses of newspaper can be used. Such markers must be weighted with stones to hold them against the wind. Bentonite and similar soluble powders cannot be relied on to remain visible for several days; they may be washed away by rain.

Six-foot squares of cloth or paper make markers of good size for airplane sowing jobs. In open country they should be spaced $\frac{1}{4}$ mile apart, but closer spacing may be required if the sowing boundary is irregular. Markers are more easily seen on prominent ridges than on secondary ridges or in canyons; cloth spread over a bush is more easily seen than cloth or paper laid flat on the ground.

Communications

Radio communications between the operations base and vantage points in the sowing area will facilitate large projects of several thousand acres, but is not usually required on the smaller jobs. If radio is used, special operators should be provided because the flagmen and checkers can not handle it in addition to their other duties.

In the sowing jobs done to date, it has not been found desirable to equip the airplane with radio, since visible signals have been adequate for communication between the flagmen and checkers, and the pilot. The signals are made with flags, arms, and airplane maneuver as follows:

a. To inform pilot of flagman's location. Flagman raises flag over head and waves it back and forth in a plane perpendicular to the airplane's line of flight. When the flagman is standing in direct sunlight, the use of a mirror is the best means of signalling a pilot approaching from a distance. An Air Corps signal mirror of the slotted type, about 2½ by 4 inches in size, is most convenient for this use.

b. To inform pilot to fly farther to right or left, to adjust for wind-drift of seed. Flagman holds flag extended upward at 45 degree angle toward side to which pilot should steer.

c. To inform pilot that he is out of seed. Flagman lays flag on ground.

d. To advise pilot to increase the sowing rate. Flagman waves flag back and forth across his knees, to advise pilot to watch closely for arm signal to follow. When pilot acknowledges by wiggling wings and circling, flagman drops flag and extends arms upward at 45 degree angle, Y-fashion, turning to keep facing pilot until signal is acknowledged.

e. To advise pilot to decrease the sowing rate. Flagman waves flag back and forth across his knees, as in d. above. When pilot acknowledges, flagman drops flag and extends arms downward at 45 degree angle ~~parallel above head,~~ turning to keep facing pilot until signal is acknowledged.

f. Calling-in the flagman. Plane circles flagman or pilot gives some other preferred signal. Sowing operations may be suspended at any hour of the day because of unfavorable weather, low gasoline supply, engine trouble, etc. It is important that the end of sowing be signalled so that the flagman will not be left out on the burn until a messenger can reach him.

APPENDIX 5

SPECIFICATIONS FOR AIRCRAFT SERVICE IN SOWING MUSTARD SEED[10]

It is essential that the aircraft used for mustard sowing have enough power for effective and safe operation close to the ground at the altitude at which sowing is done. In addition, there are field responsibilities, and details of organization and operation, that must be clearly understood by the sowing agency and the flying contractor. The job and service specifications given below have been found to be a desirable minimum. Suitable clauses to insure understandings regarding liability, the posting of performance bonds, and certification of the work before payment is made should also be included in the specifications for aircraft service.

GENERAL

The aircraft and such personal services of pilot(s) and mechanics required in these specifications are for use in sowing mustard seed on ...... acres recently burned-over within the .... National Forest, operating over rugged ground terrain that ranges from .. feet to ... feet above sea level, as shown on the map(s) attached hereto[11]

Details of the areas to be sown will be furnished by the ...(sowing agency)......... by map and general reconnaissance.

The contractor will be expected to obtain all waivers and authorizations to allow him to operate the aircraft in connection with fulfillment of this contract; however the ....(sowing agency)...... will assist in any way possible to obtain such authority, waiver, etc., and permits to utilize the best available flying fields.

Flights under this contract involve hazardous combinations of altitude, rugged topography, and weather. Their successful completion requires experienced pilots and good equipment with sufficient power to enable the aircraft to get down into deep and narrow canyons and maneuver without danger of crashing into the canyon walls.

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[10] Revised February 1948 by the Forest Service Regional Office, R-5, and the California Forest and Range Experiment Station.

[11] Two maps are usually desirable: (1) section of current C.A.A. Sectional Aeronautical Chart, and (2) topographic map showing area(s) to be sown. The area covered by the topographic map should be clearly indicated on the C.A.A. chart.

SPECIFICATIONS

1. Seed will be furnished by the .(sowing agency)....... and delivered to the pilot at points agreed upon, in or near the burned area, without cost to the contractor.

2. The ...(sowing agency)....... will provide, without cost to the contractor, adequate storage facilities for the seed up to the time it is loaded into the aircraft; the trucks required to transport seed as needed in conduct of the job; and the man-power required to make the sowing test(s), load seed into the aircraft and mark sowing boundaries within the burned area.

3. The mustard seed is to be sown at from approximately 3 to 6 pounds per acre, depending upon the size of seed furnished for the job. The determination of seed size and the number of pounds to be sown per acre will be made on the job by the ....(sowing agency).....

4. After award is made to the contractor and prior to actual starting of the sowing, a representative of the ...(sowing agency)...... will, in company with the pilot, conduct a sowing test with the aircraft to be used and will determine the proper adjustment of the seed release mechanism to be used in sowing. Such test(s) should not exceed 4 hours total time. The test(s) will be made at the expense of the contractor in or near the burned area, just before the start of the sowing job.

5. The work is to begin within 10 calendar days after receipt of the contractor's notification to proceed with the job. It is expected that such notification will be given about .....(date)...........

6. The work is to be completed as rapidly as flying conditions permit. It is assumed that from 3 to 5 early morning hours will be the best for flying, owing to adverse air conditions that may prevail later in the day.

7. The contractor will be required to provide the stipulated aircraft licensed by the Department of Commerce in approved mechanical condition, together with all equipment required for proper and complete fulfillment of the service requirements as outlined in and made a part of these bid specifications.

8. During any part of the period covered by the contract, the decision of an inspector from the Civil Aeronautics Administration, Department of Commerce, as to the serviceability of the aircraft will be accepted as final.

SERVICE REQUIREMENTS

The aircraft supplied shall:

1. Be equipped with engine(s) capable of developing adequate h.p. with reserve power for safe operation over rugged terrain up to the maximum altitude at which sowing will be done.

2. Have a minimum payload capacity of 400 pounds with a service ceiling of at least 10,000 feet.

3. Be equipped with seed hopper and seed releasing mechanism capable of adjustment to provide uniform ground distribution of from 10 to 30 mustard seeds per square foot, final adjustment to be made on the job with the seed that is actually to be sown.

4. Be equipped with adequate safety devices for the protection of ...(employee of the sowing agency)... should it be necessary for him to accompany a flight.

Fixed-wing aircraft

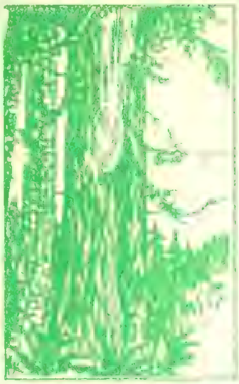
5. Airplanes in first class condition with low-time engine(s) capable of developing adequate h.p. (see Item 1 above), a payload of at least 500 pounds, and a service ceiling of 10,000 feet or more are preferred. Such payload shall include only the weight of the cargo furnished by the ......(sowing agency)........

6. Experience has shown that the flight elevation above ground while sowing should not exceed 300 feet.

Rotary-wing aircraft

7. The helicopter supplied shall be adequately powered for jump takeoff, hovering with ground effect, spot landing, and safe operation at elevations up to 5,000 feet, with minimum of 175 pounds payload in excess of flight crew and fuel for 45-minute flight.

8. Experience has shown that the seed should be broadcast at a height of about 50 feet above the ground.



FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W. TALBOT, Acting Director

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SITE PREPARATION AS AN AID TO SUGAR PINE REGENERATION[1]

H. A. Fowells, Associate Silviculturist

On many thousands of acres of cut-over timber lands in California, brush of various species has gained such control of the soil that the success of natural reproduction is problematical. This condition is particularly serious in the high site quality sugar pine-white fir and sugar pine-ponderosa pine types,[2] where the maintenance of sugar pine in the stands is a silvicultural objective. Observations have indicated that sugar pine seedlings are not able to compete successfully enough with established brush to insure a desirable stand. To take advantage of the infrequent heavy sugar pine seed crops, it appears that brush competition should be removed to increase the chances of natural reproduction. This study was designed, therefore, (1) to determine whether clearing the brush from unstocked areas during a good sugar pine seed year would foster natural regeneration of sugar pine, (2) incidentally to compare the effectiveness of three methods of establishing reproduction: natural seeding, seed spotting, and planting on the cleared areas.

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[1] Grateful acknowledgment is made to E. A. Morrow, California Forest and Range Experiment Station, who directed site preparation, and to Duncan Dunning, California Forest and Range Experiment Station, who reviewed the plans and results of the study.

[2] Sugar pine, Pinus lambertiana; ponderosa pine, P. ponderosa; white fir, Abies concolor.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Agriculture--Berkeley

Procedure

Areas treated.- The study was conducted on the Stanislaus National Forest near the Stanislaus Branch, California Forest and Range Experiment Station. Four general locations were selected for treatment, a south slope with a ground cover of bear-clover (*Chamaebatia foliolosa*) and three north slope locations with a ground cover of high brush, primarily whitethorn (*Ceanothus cordulatus*). Specific areas selected for clearing were about half a chain square, were not stocked with seedlings, and were within 150 feet of a bearing sugar pine seed tree. During the latter part of August 1941, 17 such areas were cleared in bear-clover and 20 in high brush. On the south slope, surrounding the plots in the bear-clover, there were 13 bearing sugar pine seed trees on which a total of 458 cones were counted. Surrounding the plots in high brush on the north slope there were 19 bearing trees on which 1,419 cones were counted. In comparison to cone crops observed over a period of years, this crop would be classed as heavy.

Clearing.- The brush was removed by means of a 20 h.p. tractor equipped with a toothed blade designed by the Division of Plant Disease Control[3] to eradicate concentrated *Ribes*. In high brush the rooting out of a few clumps often cleared the entire area. In bear-clover, however, it was necessary to cover the area in two directions, at right angles to each other. After the brush was removed, the tractor was backed across with the blade lowered to level the soil. The tractor driver was assisted by a helper who located hidden stumps, logs, and boulders, and cleaned brush from the teeth of the blade. An average of about 30 minutes was required to strip the brush from each area. A tractor with more power and a blade with teeth spaced farther apart so that dirt would not pile up would have decreased the time considerably.

Plot design.- In each of the 37 cleared areas a plot 24 feet square was laid out. Each plot was divided into 64 quadrats, 3 feet square, 4 of which were designated for sampling seed supply, 16 for natural reproduction, 16 for seed spotting, and 16 for planting. The remaining 12 quadrats were available for shifting any of the natural, seed-spot, or planting quadrats to avoid rocks or stumps.

Sampling seed supply.- Four seed traps, 2.86 feet square inside dimension, were placed in each plot during the first part of September to sample the seed fall on the plots.

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[3] Offord, H. R., J. F. Beakey, and L. P. Winslow. The eradication of upland *Ribes* by power equipment. Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine, Berkeley, California, March 12, 1940. (Office report, typewritten.)

Natural reproduction.- Quadrats reserved for sampling natural reproduction were disturbed as little as possible during the process of seed sampling and planting.

Seed spotting.- On November 12, 1941, five seeds were planted about one-half inch deep in each of the 16 seed-spot quadrats per plot. Each seed spot was covered with a conical hardware cloth rodent screen set about 2 inches into the soil. The seed was a local lot that had just been collected.

Planting.- A sugar pine 1-1 transplant was planted on November 12, 1941, by the side-hole method in each of the 16 quadrats of each plot. The stock was obtained from the Feather River nursery a few days prior to planting.

Results

Seed supply.- In November 1941, there were on an average, 1.4 good sugar pine seeds per trap in the bear-clover plots and 2.6 good seeds per trap in the high brush plots. On the basis of this sample, it might be expected that about 70 percent of the natural reproduction quadrats would have received one or more good sugar pine seeds.

Natural seedlings.- During the spring and summer of 1942, only 17 natural seedlings germinated in 14 of the 592 natural reproduction quadrats of the 37 plots. Only 5 seedlings were alive at the end of the first season. Natural reproduction thus was practically a failure.

Seed spots.- In the first season one or more seedlings germinated in 92 percent of the seed spots. In 27 percent of the spots, all 5 seeds germinated. On the basis of total number of seeds planted, the rate of germination was 68 percent.

The percent of seed spots stocked, the average number of seedlings per stocked spot, and the average height of the tallest seedling per spot are given in table 1 for the first 3 years of the study.

Table 1.- Survival and height of seedlings in seed spots on cleared sites

Former cover	Stocked seed spots			Seedlings per stocked seed spot			Height[1] of tallest seedling per spot	
	1942	1943	1944	1942	1943	1944	1943	1944
	Percent	Percent	Percent				Inches	Inches
Bear-clover	59	21	15	2.9	2.0	1.8	1.7	2.2
High brush	87	75	67	3.1	2.8	2.7	2.6	3.6

[1] Height measured from cotyledon scar.

Planted stock.- Survival and height of the planted trees are given in table 2.

Table 2.- Survival and height of planted stock on cleared sites

Former cover	Survival			Height[1]	
	1942	1943	1944	1943	1944
	Percent	Percent	Percent	Inches	Inches
Bear-clover	58	38	34	4.7	5.4
High brush	47	45	41	5.1	6.6

[1] Height measured from the cotyledon scar.

Discussion

It is obvious that, in spite of a heavy seed crop, natural reproduction was practically a failure. The failure was probably the result of rodent depredations. Clearing of the small areas very likely provided a very good opportunity for rodents to find the large sugar pine seeds. Site preparation to take full advantage of seed crops should be accompanied by thorough rodent control.

In the area cleared of high brush, seed spotting was more effective than planting. In the bear-clover area, however, planting was more effective. This might be explained by the fact that the bear-clover sprouted back so quickly that by the second season it had overtopped the seedlings. The planted stock, being several inches taller, was not so completely dominated.

After 3 years very little of the high brush species has sprouted back or has grown from seed in the cleared areas. It appears quite probable that the sugar pine from the seeding and planting will become established in these before the brush can regain control.

Summary

The brush cover of bear-clover or high brush was removed mechanically from 37 unstocked areas in cut-over stands in anticipation of a good sugar pine seed crop. In the cleared areas, plots were established to determine whether natural seedlings would result and to compare the effectiveness of natural reproduction, seed spotting under screens, and planting.

In spite of a good seed fall, natural reproduction was a failure, probably because of rodent depredations.

After 3 years, seed spotting was less effective than planting in areas cleared in bear-clover but was more effective than planting in areas cleared in high brush. A fair percentage of the sugar pine from seed and planting survived and grew well through the third season, indicating possibilities of successful establishment before brush regains control.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
M.W.TALBOT, Acting Director

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DIAMETER-CLASS VOLUME TABLES FOR CALIFORNIA OLD-GROWTH TIMBER

by

Duncan Dunning, Senior Silviculturist

Tables giving average tree volumes by breast-height diameter classes frequently may be used in timber cruising to save money, time, and men. Such tables may be appropriate in cruises of large areas having many trees, in low-intensity cruises warranting the sacrifice in accuracy that results from omission of individual tree height measurements, during wartime when men are scarce or when inexperienced cruisers have difficulty in estimating heights. In response to numerous recent requests from cruisers and forest land agencies, nine of the more important tables used by the Forest Service in California are here presented in diameter class form.

These tables are derived from the standard Region 5 (California) site class tables (separately identified in footnotes) by reading the volume for the tree of average height in each diameter class. The average heights, also given in the tables, were read from D.B.H. - merchantable height curves drawn from the original tree measurements used in constructing the site-class tables. The log rule used is the Scribner Decimal "C". The trees were scaled in 16-foot logs with 0.3 ft. trimming and 1.5 ft. stump allowances to a top diameter inside bark of 8 inches.

The only tables thus far converted to the diameter class form are for ponderosa pine, sugar pine, and white fir. From records in the California Forest and Range Experiment Station tables for several other species can be similarly converted if this first series proves to be satisfactory.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

VOLUME TABLES FOR CALIFORNIA OLD-GROWTH TIMBER

PONDEROSA PINE[1]

Board Feet - Scribner Decimal "C" Rule

	Site I - 175[2]		Site II - 150[2]		Site III - 125[2]		Site IV - 100[2]	
D.b.h.	Height[3]	Volume	Height[3]	Volume	Height[3]	Volume	Height[3]	Volume
Inches	16' logs	10 B.f.	16' logs	10 B.f.	16' logs	10 B.f.	16' logs	10 B.f.
12	1.7	5	2.1	7	1.8	7	1.1	3
14	2.4	10	2.9	13	2.6	14	1.9	8
16	3.0	15	3.5	20	3.2	21	2.6	14
18	3.6	23	4.0	29	3.7	30	3.2	22
20	4.2	33	4.5	39	4.1	40	3.7	32
22	4.8	48	4.9	54	4.4	53	4.1	44
24	5.3	64	5.3	69	4.7	68	4.4	59
26	5.8	83	5.7	90	5.0	87	4.6	75
28	6.3	106	6.1	114	5.2	108	4.8	98
30	6.7	136	6.4	142	5.4	133	5.0	115
32	7.1	173	6.7	174	5.6	163	5.2	144
34	7.5	213	7.0	210	5.8	193	5.4	172
36	7.9	256	7.3	250	6.0	226	5.6	206
38	8.3	303	7.6	293	6.2	261	5.8	237
40	8.7	355	7.8	336	6.4	302	5.9	268
42	9.0	406	8.0	382	6.6	345	6.0	309
44	9.3	464	8.2	434	6.8	393	6.1	349
46	9.6	527	8.4	492	7.0	446	6.2	400
48	9.8	588	8.6	554	7.2	504	6.3	446
50	10.0	653	8.8	621	7.3	556	6.4	492
52	10.2	722	9.0	692	7.4	613	6.5	531
54	10.4	796	9.2	769	7.5	675	6.6	582
56	10.5	870	9.4	856	7.6	742	6.7	627
58	10.6	948	9.5	938	7.7	813	6.8	677
60	10.7	1031	9.6	1025	7.8	888	6.8	729
62	10.8	1118	9.7	1117				
64	10.9	1206	9.8	1217				
66	11.0	1300	9.9	1324				
68	11.1	1394	10.0	1440				
70	11.2	1499	10.1	1562				
72	11.2	1590						

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[1] Volumes for Sites I-175, II-150, and III-125 are from USFS site-class tables for Region 5 prepared by Duncan Dunning in 1942. Volumes for Site IV-100 are from Research Note No. 32, Calif. Forest and Range Exp. Sta., Taper and Volume Tables for Ponderosa Pine on Site IV-100 in California, by R. F. Keniston and V. A. Clements, Berkeley, Calif., May 10, 1943.

[2] Total height in feet of average dominant trees at 300 years. For description of site classes see Research Note No. 28, Calif. Forest and Range Exp. Sta., A Site Classification for the Mixed-Conifer Selection Forests of the Sierra Nevada, by Duncan Dunning, Berkeley, Calif., Dec. 1, 1942.

[3] To 8 inches top diameter, inside bark. To convert to height of top section above ground in feet, multiply the number of logs by 16.3 and add 1.5. Thus the average merchantable height of the 20-inch trees on Site I-175 is:
4.2 (16.3) + 1.5 = 70 feet.

VOLUME TABLES FOR CALIFORNIA OLD-GROWTH TIMBER

SUGAR PINE[1]

Board Feet - Scribner Decimal "C" Rule

D.b.h.	Site I - 175[2]		Site II - 150[2]	
	Height[3]	Volume	Height[3]	Volume
Inches	16' logs	10 B.f.	16' logs	10 B.f.
12	1.6	5	1.3	4
14	2.2	9	2.1	10
16	2.8	14	2.8	16
18	3.4	21	3.5	24
20	3.9	29	4.1	34
22	4.4	41	4.7	48
24	4.9	55	5.2	64
26	5.4	73	5.6	81
28	5.8	92	5.9	100
30	6.2	113	6.2	121
32	6.6	140	6.4	142
34	7.0	170	6.6	167
36	7.4	206	6.8	195
38	7.8	245	7.0	225
40	8.2	287	7.2	258
42	8.5	330	7.35	292
44	8.8	360	7.5	330
46	9.1	434	7.65	375
48	9.4	494	7.8	422
50	9.6	552	7.95	478
52	9.8	614	8.1	533
54	10.0	677	8.25	595
56	10.2	745	8.4	663
58	10.3	810	8.55	737
60	10.4	872	8.7	804
62	10.5	940	8.85	863
64	10.6	1014	9.0	918
66	10.7	1080	9.15	969
68	10.8	1150	9.3	1016
70	10.8	1210	9.4	1063
72	10.9	1277	9.5	1122
74	10.9	1337	9.6	1188
76	11.0	1409	9.7	1256
78	11.0	1473	9.8	1330
80	11.0	1540	9.9	1410
82	11.1	1622	10.0	1492
84	11.1	1690	10.1	1578
86	11.1	1758	10.2	1666
88	11.1	1823	10.3	1754
90	11.1	1892	10.4	1845
92	11.1	1962		
94	11.2	2052		
96	11.2	2123		
98	11.2	2199		
100	11.2	2275		

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[1] Volumes are derived from USFS, Region 5, tables for Sites I and II, prepared by Duncan Dunning in 1925.

[2], [3] See footnotes 2 and 3, ponderosa pine table, p. 2.

VOLUME TABLES FOR CALIFORNIA OLD-GROWTH TIMBER

WHITE FIR[1]

Board Feet - Scribner Decimal "C" Rule

	Site I - 175[2]		Site II - 150[2]		Site III - 125[2]	
D.b.h.	Height[3]	Volume	Height[3]	Volume	Height[3]	Volume
Inches	16' logs	10 B.f.	16' logs	10 B.f.	16' logs	10 B.f.
12	1.8	6	1.0	5	1.0	4
14	2.5	10	1.9	9	1.6	8
16	3.2	17	2.7	16	2.2	12
18	3.9	27	3.4	24	2.8	18
20	4.5	39	4.0	35	3.4	27
22	5.1	57	4.6	50	4.0	40
24	5.6	76	5.1	66	4.5	55
26	6.1	99	5.5	84	4.9	71
28	6.5	124	5.9	105	5.3	88
30	6.9	151	6.3	127	5.6	104
32	7.3	183	6.6	151	5.9	122
34	7.7	217	6.9	176	6.2	154
36	8.0	253	7.2	204	6.5	181
38	8.3	291	7.5	237	6.7	212
40	8.6	334	7.8	273	6.9	242
42	8.9	379	8.0	308	7.1	275
44	9.2	429	8.2	345	7.3	311
46	9.5	480	8.4	386	7.5	349
48	9.7	532	8.6	431	7.7	390
50	9.9	585	8.8	478	7.9	435
52	10.1	639	9.0	528	8.1	481
54	10.3	695	9.2	580	8.2	525
56	10.5	750	9.4	633	8.3	572
58	10.7	810	9.5	685	8.4	621
60	10.8	867	9.6	740	8.5	674
62	10.9	930	9.7	804		
64	11.0	990	9.8	861		
66	11.1	1051	9.9	934		
68	11.2	1108				
70	11.3	1158				
72	11.4	1220				

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[1] Volumes for Sites I-175 and II-150 are from USFS, Region 5, site-class tables prepared by Donald Bruce in 1921. Volumes for Site III-125 are from the Region 5 Site III table prepared by Duncan Dunning in 1921.

[2], [3] See footnotes 2 and 3, ponderosa pine table, p. 2.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

No. 44

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FIRST-SEASON RECORDS OF CATTLE WEIGHTS FROM A PINE-TIMBER RANGE AND A MOUNTAIN MEADOW RANGE

By

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Grazing grounds in the mountains of northeastern California furnish summer forage for large numbers of cattle and sheep. The most efficient utilization of this forage poses problems of concern to both the stockman and the public-land administrator. One of these problems centers around the value of forage grown in the timber type (fig. 1) compared with that grown in the meadows and flats (fig. 2) — the subject of this report.

These summer cattle ranges consist of intermingled meadow, sagebrush, and open pine-timber types. Cattle graze principally in the meadows and surrounding sagebrush fringes from May or June until late August or early September. Only after that time do they graze very much in timber and brushy types on the adjoining mountain slopes. This tendency of cattle to graze on certain areas is influenced by many factors including differences in tree and brush cover, forage, and topography, and the location and adequacy of livestock watering places and fences for controlling the distribution of the animals. The result is uneven grazing of the range.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Concentration of cattle on meadows year after year is decreasing forage production and contributing to losses in soil fertility through erosion. It is estimated that on the average the grazing capacity of many unfenced meadows in northeastern California is one-half or less of former capacity. In contrast many timber-type ranges are not fully utilized. Maximum grazing values are not derived from these timber types because the forage is grazed mainly after it is mature and dry, when nutritional values are low. Because of the uneven distribution of cattle on the range, therefore, valuable meadow and sagebrush grazing lands are gradually being destroyed and much forage on timber-type ranges is being wasted.

Study of this problem of mountain-range management was begun in 1936 at the Burgess Spring Experimental Range (a branch of this Station) on the Lassen National Forest[1/]. This project is yielding information on the character, condition, grazing capacity, and value of pine-timber, sagebrush, and meadow types. This information is needed to provide a basis for determining how these types can be used most profitably for cattle grazing, with due consideration to timber growing, game and other wildlife production, recreation, and other important uses of these mountain lands. Initial studies during 1936, 1937, and 1938 showed that cut-over pine-timber range has high grazing value. During these three seasons mixed groups of beef cattle -- yearling steers and heifers and dry cows 3 years old and older -- grazed in a pasture containing only cut-over pine-timber range gained an average of $1\frac{1}{2}$ to 2 pounds per day per head during a 100-day grazing season from June to September.

During the 1944 season, the first data on the comparative value of timber and meadow types were obtained. These initial findings are reported here.

1/ Personnel of the Lassen National Forest, particularly P. D. Hook and P. B. Lord, and F. P. Cronemiller and associates of the Division of Range Management of the Regional Office of the Forest Service in San Francisco, participated in the planning and conduct of this experiment. During 1936, 1937, and 1938 the Cone Ranch Company, Red Bluff, managed by Roy Owens, furnished the experimental cattle. In 1944 the cattle were provided by J. I. and J. P. McClelland of Standish. T. S. Brown, farm adviser of Lassen County, and V. M. Shepard, animal husbandry specialist of the Extension Service, are giving attention to the animal husbandry phases of the experiment, involving grading to insure uniformity of experimental herds and selection for breeding and herd improvement.

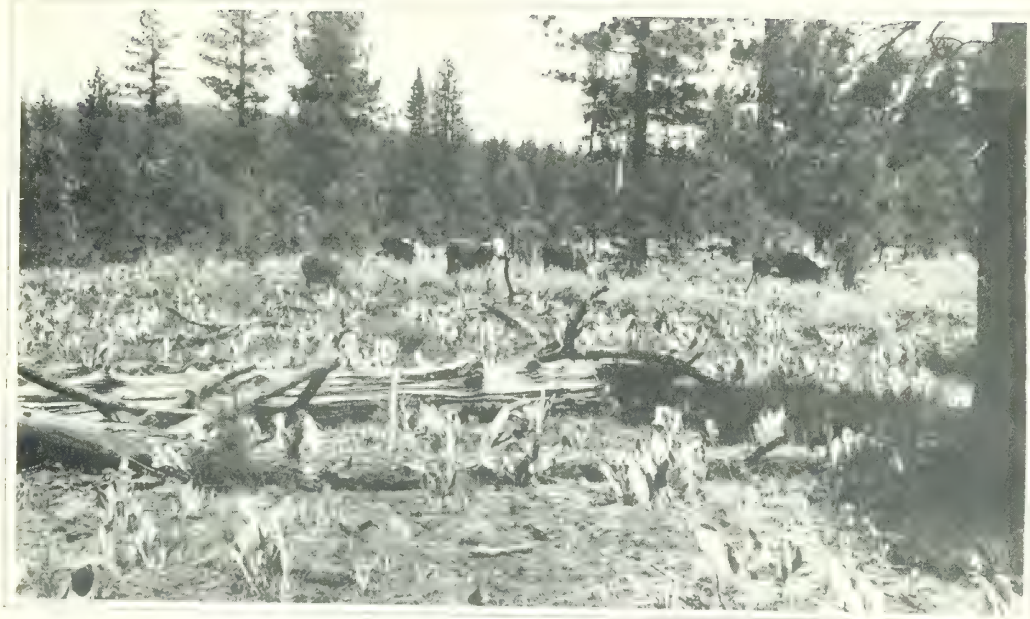


Fig. 1. Experimental cattle in timber-type pasture.

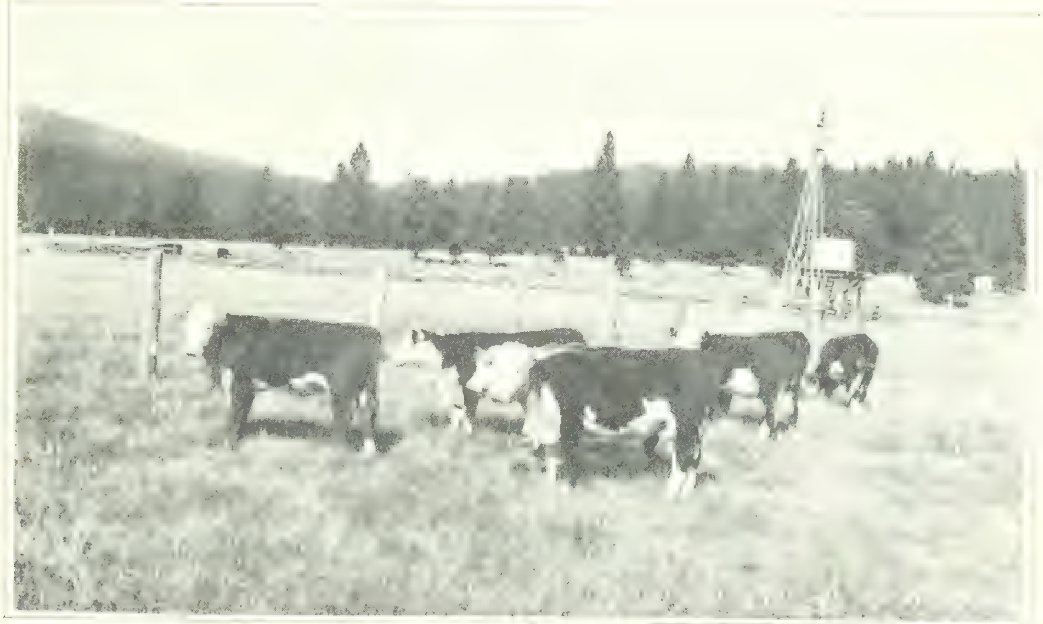


Fig. 2. Experimental cattle in mountain meadow pasture.

THE PASTURES

Ponderosa and Jeffrey pine (*Pinus ponderosa* and *P. jeffreyi*) and a few small clumps of white fir (*Abies concolor*) make up the tree cover in the timber pasture, which lies at a mean altitude of about 6,000 feet. In 1934, 85 percent of the timber stand of about 15,000 board feet per acre was removed in logging. The stand consisted primarily of mature and overmature trees and grew on medium to low timber-producing land.

In the timber pasture the eight most important forage species are Idaho fescue (*Festuca idahoensis*), spur lupine (*Lupinus calcaratus*), bitterbrush (*Purshia tridentata*), squirreltail (*Sitanion hystrix*), cheatgrass (*Bromus tectorum*), sedge (*Carex rossi*), needlegrass (*Stipa* spp.) and woolly mule ears (*Wyethia mollis*). These with more than 100 other herbaceous and shrubby species form a ground cover of about 0.34 density. Big sagebrush (*Artemisia tridentata*) is a conspicuous element of the understory vegetation and makes up about 10 percent of the ground cover, but it is not grazed by cattle. Forage species cover about 0.24 of the ground.

The meadow pasture supports a mixture of plants averaging about 0.4 density. This relatively low density for meadow vegetation is the result of past deterioration of the plant cover. On areas that remain moist throughout most of the season, sedges and rushes (*Juncus* spp.), tufted hairgrass (*Deschampsia caespitosa*), water groundsel (*Senecio hydrophilus*), cinquefoil (*Potentilla gracilis*), and other less abundant forage species form a solid ground cover. On better drained soils bordering these wet spots the important forage species are Nevada bluegrass (*Poa nevadensis*), mat muhly (*Muhlenbergia squarrosa*), California hairy oatgrass (*Danthonia californica*) and a rush (*Juncus balticus*). In the drier portions of the meadow, interspersed in open stands of low sagebrush (*Artemisia arbuscula*) and silver sagebrush (*A. cana*), the most important forage species are squirreltail, junegrass (*Koeleria cristata*), Sandbergs bluegrass (*Poa secunda*), shorthair sedge (*Carex exserta*), and Idaho fescue. In the meadow low sage brush, buttercup (*Ranunculus alismaefolius*), and biscuitroot (*Cogswellia* spp.) are conspicuous and fairly abundant but of little value as forage.

THE EXPERIMENT

One group of 10 yearling Hereford heifers grading "medium" to "good" was grazed season-long in a 555-acre cut-over pine timber pasture. Another similar group of cattle was grazed in an adjoining 128-acre mountain meadow for the same period. Grazing was started on June 2 and stopped on October 31. Care was exercised in stocking both pastures to insure an adequate supply of forage for the cattle. Thus the weight gains of the animals reflect the nutritive qualities of the forage.

Corrals and livestock scales are centrally located between the two pastures and stock water is available in each. The cattle were weighed individually to the nearest 2 pounds on a shrunk weight basis every 2 weeks throughout the season. The cattle were held in the corrals without food or water overnight, for 15 hours, before each weighing. Measurements of plant growth and development were made at 2 week intervals to correlate forage value with cattle weights.

RESULTS

The cattle grazed in the timber type gained about the same weight as the cattle grazed in the meadow and maintained weight longer in the fall (fig. 3, p. 6, and table 1, p. 7). The average maximum gain of the timber cattle was 214 pounds per head and of the meadow cattle 213 pounds per head. The 1-pound difference is not significant. The total gain per head made by the cattle in the timber pasture during the entire season was 205 pounds, and that made by the meadow group was only 186 pounds. Most of this difference of 19 pounds is the result of a 27 pound loss in weight of the cattle in the meadow during October, when those in the timber lost only 9 pounds. The meadow herd, however, began to gain weight about 5 or 6 days earlier and reached maximum weight 17 days earlier than the timber herd.

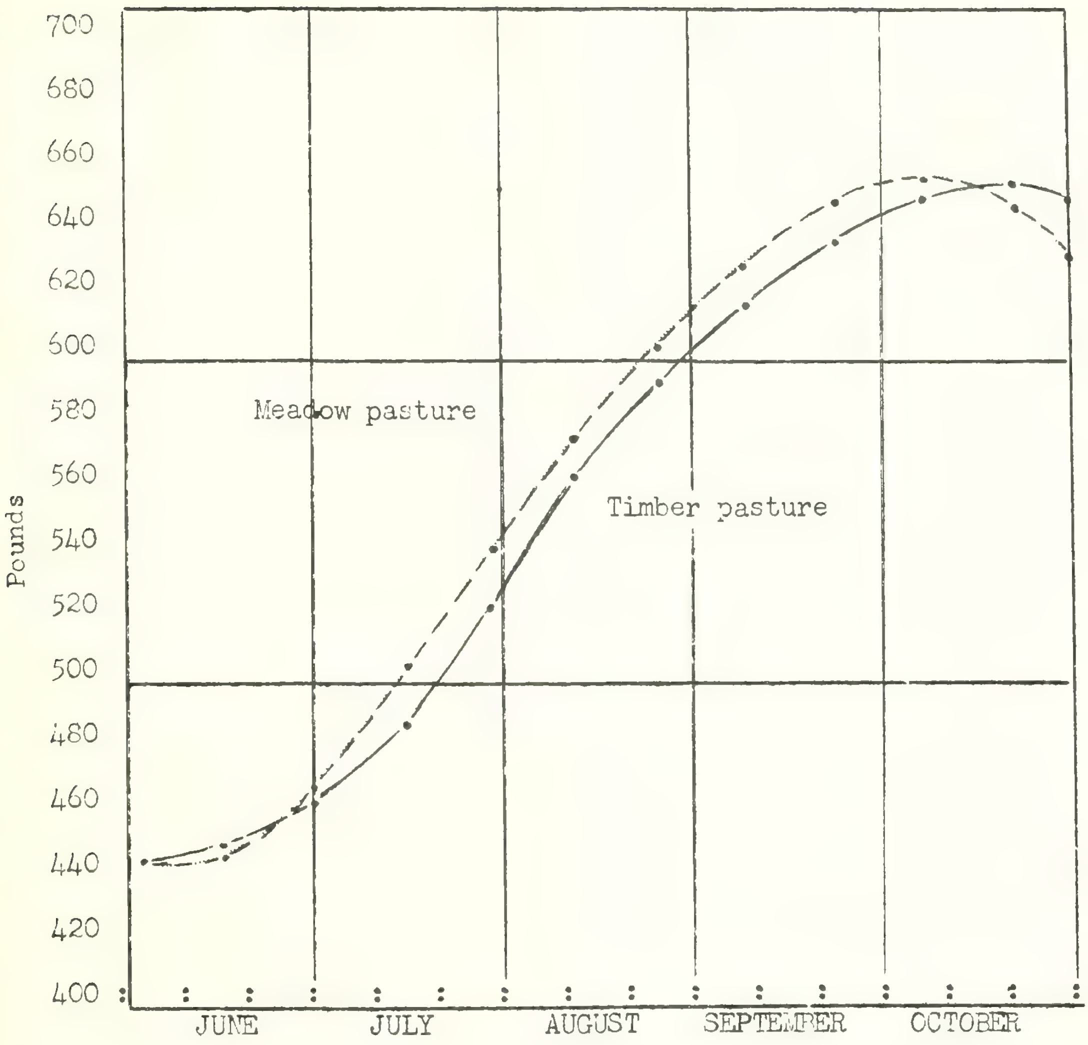


Fig. 3.- Trend in average weight per cow in each herd throughout the 1944 grazing season.

Table 1.- Cattle weights at 2-week intervals in 1944 grazing season (151 days).

												Weight gain	
Animal No.	June 2	June 16	June 30	July 14	July 28	Aug. 11	Aug. 25	Sept. 8	Sept. 22	Oct. 6	Oct. 20	Oct. 31	Maximum 1/	Total f season
							Pounds							
							Animals grazed in timber pasture							
1	488	488	491	506	547	596	631	659	678	692	698	697	211	209
6	397	397	408	433	466	500	529	557	576	587	589	579	193	182
7	398	404	416	441	482	525	554	576	594	607	610	601	213	203
8	561	552	553	574	612	652	680	703	721	734	734	712	175	151
11	360	364	383	412	442	472	498	524	542	553	554	544	195	184
12	535	539	557	595	639	682	721	754	782	802	807	796	273	261
14	426	440	463	493	528	565	594	618	636	648	655	657	231	231
17	380	389	406	434	477	513	540	559	573	582	585	584	205	204
23	470	476	489	511	548	592	625	654	676	689	695	687	225	217
30	419	432	454	483	512	540	566	590	611	628	635	630	216	211
Average	443	448	462	488	525	564	594	619	639	652	656	649	214	205
							Animals grazed in meadow pasture							
2	413	415	431	470	514	548	575	603	625	636	626	610	223	197
4	424	425	444	475	509	539	569	595	612	615	603	588	192	164
10	428	430	451	482	514	541	564	585	600	608	603	572	180	144
15	515	516	545	594	639	675	705	731	750	761	760	744	247	229
16	535	540	567	607	647	670	695	735	760	764	756	743	229	208
19	444	443	461	499	540	577	610	640	663	670	658	639	226	195
20	386	401	424	459	493	524	551	575	594	603	594	570	217	184
22	376	373	394	428	464	495	524	545	557	561	556	541	185	165
29	467	466	491	529	568	603	634	660	681	689	677	654	222	187
Average	443	445	468	505	543	575	603	630	649	656	648	629	213	186

1/ Gain from first weighing to greatest weight.

In both pastures most rapid gains were made when the forage was green, the maximum gain of 2.7 pounds per head per day in a 2-week period occurring in late July during the flowering period of the most important forage species. In table 2 the average daily gain per head is shown separately for each 2 week period between weighings. Most of the weight gains in both types were made from the time flower stalks began to show on the principal forage species until the forage was about 80 percent dry.

Table 2.- Average daily weight gain per head during 2 week periods, 1944 grazing season

Herd	June 2 to June 16	June 16 to June 30	June 30 to July 14	July 14 to July 28	July 28 to Aug. 11	Aug. 11 to Aug. 25	Aug. 25 to Sept. 8	Sept. 8 to Sept. 22	Sept. 22 to Oct. 6	Oct. 6 to Oct. 20	Oct. 20 to Oct. 31	Weight gain: Maximum 1/	Weight gain: Total for season
						Pounds							
Timber	0.3	1.0	1.9	2.6	2.7	2.2	1.8	1.4	1.0	0.3	0.7	1.6	1.4
Meadow	0.2	1.6	2.7	2.7	2.3	2.0	1.9	1.4	0.5	-0.6	-1.7	1.7	1.2

1/ Gain from first weighing to greatest weight.

IMPLICATIONS OF RESULTS

These first-year results have immediate value in practical management. Perhaps the major finding was the fact that cattle gained as much weight in the timber as in the meadows. Meadow forage produced earlier gains, but timber-type forage sustained weights later in the fall. Since the latter advantage is due in large measure to the presence of browse, particularly bitterbrush, reseeding of browse on suitable sites would strengthen the nutritive qualities of autumn forage in this region.

To obtain maximum production from the range, both types should be grazed throughout most of the season. Grazing should be started after flower stalks begin to show, because cattle begin to gain weight appreciably then. The cattle should be removed from the range when they begin to lose weight -- or earlier if the operator's flexibility of management permits. The indications are that more beef could be produced on the range if the cattle in the meadow were moved into the timber type during the last month of the grazing season.

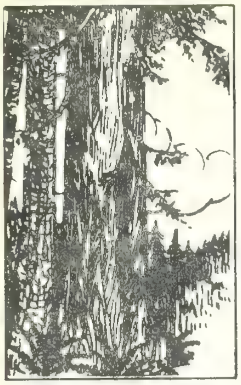
The period of weight gain is related to forage growth and not to calendar dates. For example in 1944 — a very late growing season — weight gains of cattle in the timber type were made between about June 15 and October 18 and in the meadow type between June 15 and October 5. Records obtained in the timber type show that corresponding gains in previous years were made 3 or 4 weeks earlier, in the average year from late May to September 15.

The timber pasture at Burgess Spring represents some of the best timber-type range in northeastern California. The meadow pasture is about average for the area. From past and present records it is estimated that 8 acres of the timber-pasture will provide forage for one cow for 1 month. In comparison only 2 acres of the meadow pastures are required. Roughly, therefore, 4 acres of timber-type range are needed to balance 1 acre of meadow. This ratio would probably increase to about 8 to 1 if the meadow were rehabilitated to potential capacity.

In most cases the timber type in this locality is producing about as much forage as the site will grow. Increased benefits, therefore, from the timber type as the result of improved management will be derived chiefly from greater and more timely use. In contrast the indications are that the quantity and quality of the forage in the meadow can be improved materially through management and artificial reseeding.

The differences in weight gains of different animals suggest the possibility of increasing production from this entire range area by better breeding and culling of the herd.

These results show that efficient use of this kind of mountain range depends upon close control over the movements and distribution of cattle. The findings again emphasize the importance of fencing range, developing additional sources of water, and paying close attention to salting, riding, and other practices which will bring about more uniform grazing of the range. The results further reveal the advantages of more timely grazing of each broad range type when its forage is most nutritious. Particularly significant are the beef-producing properties of timber forage in comparison with meadow forage. To obtain more complete information on the practical points involved, it is planned to continue the study for 2 or 3 more years.



FOREST RESEARCH NOTES

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STEPHEN N. WYCKOFF, Director

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

No. 45 July 15, 1945

PRODUCTION OF LUMBER, LATH, AND SHINGLES IN CALIFORNIA AND NEVADA, 1944

(Preliminary data, subject to revision)

In cooperation with the Bureau of the Census of the U. S. Department of Commerce, preliminary statistics of lumber production in California and Nevada are presented herewith. These data should be essentially correct, since they are based on preliminary tabulations of complete returns. Final statistics will, however, be issued by the Bureau of the Census in the usual manner.

Lumber production in California in 1944 reached a new high, being about 5 percent more than in the peak year of 1943. This is a remarkable industry achievement in view of the difficulties of operation centering mainly about manpower and equipment shortages. Both the pine and redwood regions registered increases this year.

The production data in tables 1, 2, and 3 are based upon reports from 319 active mills in the California pine region, and 109 active mills in the redwood region. Included in these totals are 15 active shingle mills 7 in the pine region, and 8 in the redwood region.

For the entire State and all species, the production of 2,468,943 M feet b.m. (table 1) is about 5 percent more than total State wide production in 1943. There was practically no change in the production of redwood. The most significant decrease was in the cut of ponderosa pine which fell off about 6 percent. The cut of Douglas-fir rose about 11 percent, while white fir production increased about 59 percent. In the past three years the utilization of white fir has nearly tripled. There were marked increases also in the production of other softwoods, such as Sitka spruce, incense cedar, and sugar pine. The output of sawed cross ties, nine feet or less in length, was 30,746 M feet b.m., or about 1 percent of total lumber production. Shingle production increased about 40 percent, but lath production fell off nearly 65 percent. Lumber stocks at sawmills increased from 480,788 M feet b.m. on December 31, 1943 to 538,858 M feet b.m. on December 31, 1944 - 58,070 M feet b.m., or about 12 percent. Active sawmills in the State rose from 365 in 1943 to 413 in 1944. It is estimated that there were in addition 87 sawmills which were idle throughout all of 1944, but most of these were small mills of low potential output.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

In the pine region lumber production in 1944 was 1,821,007 M feet b.m. (table 2), or approximately 5.4 percent more than the output in 1943. Increased production of white fir (+60.9 percent), sugar pine (+16.7 percent), Douglas-fir (+9.7 percent), and incense cedar (+40.7 percent), more than offset the decrease registered by ponderosa pine (-6.7 percent). The cut of ponderosa pine represented 58.2 percent of total regional production, followed by white fir representing 15.3 percent. The 33 mills cutting 15 million feet or more represented 69.3 percent of the total cut. There were 36 more active sawmills in the pine region in 1944 than in 1943, due mainly to an increase in the number of small mills. There were 11 less idle sawmills in 1944 than in 1943. The output of sawed cross ties, nine feet or less in length, was 11,841 M feet b.m., or about 0.6 percent of total lumber production. Lumber stocks increased 14.3 percent during the year, and although there was a decrease in the production of lath, the output of shingles practically doubled.

In the redwood region lumber production of 647,936 M feet b.m. was about 3.5 percent greater than the 1943 cut. Practically the same volume of redwood was cut this year as last (461 million feet). Most of the overall regional increase in production was due to an upswing in the output of Douglas-fir, which rose from 151 million feet to 171 million feet, or 13.1 percent. White fir production increased from 7,479 M feet b.m. in 1943 to 9,376 M feet b.m. in 1944. The 12 mills cutting over 10 million feet accounted for 77.5 percent of total regional production. There were 101 active sawmills in the region in 1944 as contrasted to 89 in 1943. The output of sawed cross ties, nine feet or less in length, was 18,905 M feet b.m., or about 2.9 percent of total lumber production. Lumber stocks of 77,214 M feet b.m. at the end of the year varied only slightly from the volume on hand at the beginning of the year. The output of lath was 54.4 percent less than in 1943, but shingle production increased 34.5 percent.

Table 1: Production of lumber, by kind of wood, and of sawed ties, lath and shingles California and Nevada,[1/] 1943 and 1944

(Preliminary data, subject to revision)

Species	Lumber production (M feet, b.m.)				Change in 1944 from 1943
	1943		1944		
	Quantity	Percent	Quantity	Percent	Percent
Ponderosa pine	1,135,652	48.3	62 1,060,~~55~~7	43.0	-6.6
Redwood 2/	460,829	19.6	461,937	18.7	+0.2
Douglas-fir	328,395	13.9	7 365,~~4~~87	14.8	+11.3
Sugar pine	211,047	9.0	25 246,~~32~~3	10.0	+16.7
White fir	181,017	7.7	2 288,~~5~~89	11.7	+59.~~4~~3
Incense cedar	28,856	1.2	40,596	1.6	+40.7
Port Orford cedar	3,200	0.1	2,156	0.1	-32.6
Sitka spruce	2,100	0.1	3,017	0.1	+43.7
Other softwoods	1,317	0.1	100	--	92.4
Hardwoods	179	0.0+	181	---	+1.1
TOTAL	2,352,592	100.0	2,468,943	100.0	+4.9
Sawed ties MBM 3/	-		30,746		-
Lath (thousands)	10,185		3,570		-64.9
Shingles (squares) 4/	45,090		63,371		+40.5
Stocks of lumber, Dec. 31	480,788		538,858		+12.1
Number of active mills reporting	378		428		+13.2

1/ Combined to avoid disclosing output of individual establishments.

2/ Includes big tree (Sequoia gigantea) in pine region.

3/ Represents quantity of sawed cross ties, nine feet or less in length, included under total quantity lumber sawed.

4/ Includes shakes reported as such.

Table 3:- Production of lumber, by kind of wood and class of mill, and of sawed ties, lath and shingles
California Redwood Region[1] 1944
(Preliminary data, subject to revision)

Class of mill	Total mills		Lumber sawed (M feet, b.m.)							Total		Lumber on hand		Sawed[2] cross ties	Lath	Shingles[3]
	Idle	Active	Redwood	Douglas fir	White fir	Sitka spruce	Port Orford cedar	Ponderosa pine	Hardwoods	Quantity	Percent	Dec. 31, 1943	Dec. 31, 1944			
	No.	No.										MBM	MBM	MBM	M pcs.	Squares
8 (50 MM and over)	0	4	238,745	47,904	2,466					289,115	44.7	48,834	48,760	13,016	165	25,179
7 (25 MM to 50 MM)	0	4	117,821	12,716	2,323					132,860	20.5	16,516	18,735	3,404	2,704	7,593
5 and 6 [4] (10 MM to 25 MM)	0	4	43,878	29,312	3,787	2,941				79,918	12.3	5,292	4,086	1,445	182	1,787
4 (5 MM to 10 MM)	1	8	31,992	27,659			1,507			61,158	9.4	3,511	4,408	40		
3 (1 MM to 5 MM)	2	28	20,613	46,431	500		638	237		68,419	10.6	326	579	381	50	
2 (500 M to 1 MM)	4	15	4,249	4,~~3~~656	~~300~~			616		9,521	1.5	340	542	412		150
1 (50 M to 500 M)	7	31	3,719	2,388		72		395	178	6,752	1.0	8	104	189		1,125
0 (under 50 M)	6	7	87	91		4	11			193	-	0	0	18	300	10
Shingle	4	8														25,346
All classes	24	109	461,104	17~~0~~1,~~8~~157	9,~~3~~076	3,017	2,156	1,248	178[5]	647,936	100.0	76,827	77,214	18,905	3,401	61,190

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[1] Redwood region includes counties of Del Norte, Humboldt, western Mendocino, Sonoma, western Napa, Marin, Santa Clara, San Mateo, Monterey and Santa Cruz. Remainder of State considered the pine region.

[2] Represents quantity of sawed cross ties, nine feet or less in length, included under total quantity lumber sawed.

[3] Includes shakes reported as such.

[4] Classes 5 and 6 combined to avoid disclosing cut of individual mills. There are 3 mills in class 6 and 1 in class 5.

[5] Includes 64 M.B.M. tanbark oak, 50 M.B.M. California black oak and valley oak, 6 M.B.M. California laurel, and 58 M.B.M. of alder.

Table 2:- Production of lumber, by kind of wood and class of mill, and of sawed ties, lath, and shingles

Pine Region1/ - California and Nevada 1944

(Preliminary data, subject to revision)

Class of mill	Total mills		Lumber sawed (M feet, b. m.)									Lumber on hand		Sawed2/ cross ties	Lath	Shingles3/
	Idle	Active	Ponderosa pine	Sugar pine	White fir	Douglas fir	Incense cedar	Other softwoods	Hard-woods	Total Quantity	Total Percent	Dec. 31, 1943	Dec. 31, 1944			
	No.	No.										MBM	MBM	MBM	M pcs.	Squares
8 (50 MM and over)	0	5	366,996	74,108	67,096	11,113	7,251			526,564	28.9	92,776	101,417	1,107		
7 (25 MM to 50 MM)	0	13	238,698	78,648	94,816	36,137	5,627			453,926	24.9	130,126	148,980	1,485		
6 (15 MM to 25 MM)	1	15	159,442	36,169	44,130	36,050	6,530			282,321	15.5	97,765	102,946	165		
5 (10 MM to 15 MM)	0	15	80,016	22,455	28,849	38.802	4,181			174,303	9.7	49,963	57,571	6,099		
4 (5 MM to 10 MM)	1	22	77,920	18,525	23,023	35,543	7,020			162,131	8.9	20,478	27,903	2,511		
3 (1 MM to 5 MM)	2	76	105,445	12,420	17,720	32,271	9,047	750		177,653	9.7	11,930	20,103	474	25	
2 (500 M to 1 MM)	4	33	16,120	2,723	2,065	2,225	507	40		23,680	1.3	460	1,423	0		250
1 (50 M to 500 M)	26	101	11 14,046	08 1,254	1,511	2,361	432	143	2	19,649	1.1	458	1,266	0		574
0 (Under 50 M)	33	32	626	21	3	128	1		1	780	-	5	35	0		20
Shingle	2	7													150	1,337
All classes	69	319	7 1,059,309	25 246,323	279,213	194,630	40,596	4/933	5/3	1,821,007	100.0	403,961	461,644	11,841	175	2,181

1/ See footnote 1/ table 3. Includes production of 1 Class 3 mill in Nevada. Other Nevada mills (4 Class 0) were idle during 1944.

2/ Represents quantity of sawed cross ties, nine feet or less in length. included under total quantity lumber sawed.

3/ Includes shakes reported as such.

4/ Includes 833 M.B.M. big tree, 80 M.B.M. western white pine, and 20 M.B.M. lodgepole pine.

5/ Entire hardwood cut is California black oak.

FOREST RESEARCH NOTES
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CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 47 December, 1947

DEPARTMENT OF [illegible]
THE UNIVERSITY OF [illegible]
[illegible]

THE SAN DIMAS LYSIMETERS:

...instruments for evaluating the water economy of chaparral vegetation...

Part 1--The lysimeter installation and
research program.

Part 2--The relative performance of four
types of lysimeters

By

E. A. Colman and E. L. Hamilton

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Agriculture--Berkeley

FORWORD

A description of the San Dimas lysimeters would be incomplete without mention of the individuals, other than the authors, and of the organizations that took part in developing this installation.

The major features of the installation were based upon lysimeters originally designed by W. C. Lowdermilk in connection with earlier projects of the Experiment Station. Persons intimately concerned with the planning and construction were E. I. Kotok, C. J. Kraebel, J. D. Sinclair, W. U. Garstka, J. S. Cotton, H. F. Jerauld, H. G. Wilm, and P. B. Rowe, all at that time members of the California Forest and Range Experiment Station staff. Invaluable aid in a consulting capacity was rendered by E. N. Munns, Chief of the Division of Forest Influences Research of the Forest Service; by F. J. Veihmeyer, G. B. Bodman, and the late C. F. Shaw, all of the University of California; and by the late F. E. Clements of the Carnegie Institution of Washington. L. F. Reimann has been responsible for many mechanical developments that have facilitated the operation of the lysimeters. Construction of the whole installation was made possible by the assistance of men and materials provided by the Civilian Conservation Corps and the Work Projects Administration. Grateful acknowledgement is made at this time for the assistance that has been derived from these many sources.

PART I — THE LYSIMETER INSTALLATION AND RESEARCH PROGRAM

The San Dimas Experimental Forest is a 17,000 acre watershed research laboratory situated in the San Gabriel Mountains of southern California. (4)[1] Here the U. S. Forest Service is studying rainfall, soil water movement, streamflow, and erosion, in a research program planned to develop the principles and practices of management for chaparral-covered watersheds. The goal of such management is the maximum production of usable water combined with minimum flood and erosion danger. The lysimeter installation of the Experimental Forest was designed for the purpose of studying the influence of certain species of chaparral vegetation upon the disposition of precipitation reaching the soil. It thus forms an integral part of the watershed-management research program for which this experimental forest was established.

Vegetation must be considered in any plan of watershed management because of its very considerable influence upon runoff, erosion, and evaporative loss of soil water, and because of the possibilities of modifying this influence by cultural treatment. The role of vegetation in watershed management may be defined in terms of its water economy, which can be measured by the influence vegetation exerts upon infiltration and soil permeability, and by its evaporation-transpiration characteristics.

It is difficult to compare directly in the field the water economy of various kinds of vegetation because of soil variability and the limited experimental control over important factors possible under field conditions. Lysimeters make possible a high degree of experimental control over soil and environment so that vegetation can be isolated as the only important influencing factor. Despite some shortcomings which will be described presently, lysimeters are the most satisfactory instruments now available for comparing the water economy of different kinds of plants.

THE PROBLEM OF LYSIMETER DESIGN

The type of lysimeter to be employed in any study depends upon the particular objective of that study. The advantages and limitations of the several types of lysimeters have been clearly presented by Kohnke et al (3), but a brief resume here will indicate the reasons underlying the choice of those used in the San Dimas study.

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[1] Numbers in parentheses refer to Literature Cited, page 14.

Lysimeters may be divided into three types: the Russian or Ebermeyer lysimeter, the "in place" or "core cutter," and the "filled" type, which is filled with soil after construction.

The Ebermeyer type consists merely of a percolate-collecting funnel buried in natural soil. It imposes no restrictions upon surface runoff or root development since it has no confining walls. Capillary forces operating in the soil surrounding the funnel cause some of the percolating water to pass around the funnel rather than into it. Because it does not intercept all the water that penetrates to the level of the funnel, it is unsatisfactory for the quantitative measurement of water seepage.

The "in place" lysimeter consists of an impervious shell (metal, concrete, or wood) placed around and under a block of undisturbed soil. By this operation the soil block is completely isolated, and collection of all surface runoff and seepage is assured. The increase in experimental control thus accomplished is accompanied by a significant departure from natural conditions, for the soil/air interface across which seepage water must pass to leave the soil results in the establishment of a saturated soil layer covering the bottom of the lysimeter during the seepage period. Seepage cannot take place unless the water-absorptive power of the soil immediately above the seepage plane has been satisfied. This condition is met only when the soil there is virtually saturated with water, which, in turn, means that a nearly saturated condition exists for some distance above this plane. The thickness of the layer of abnormally wet soil increases with increasing fineness of soil texture. The presence of this "perched water table" is characteristic of enclosed lysimeters as a group. In some "in place" lysimeters, such as those at Coshocton (6), the seepage plane is located at such a depth that a natural soil profile extending well into the parent rock has been enclosed. Such an enclosed soil block probably exhibits more nearly natural conditions than would be the case if soil rested directly on the seepage plane.

"In place" lysimeters, including as they do an undisturbed block of natural soil, are in many instances the most desirable type. However, when they are installed in soils that are not uniform, many replications must be made in order to establish the significance of results obtained from them. The "in place" lysimeter is used to best advantage for studies in which the soil itself is the variable under investigation.

For studies in which vegetation or treatment of the soil surface are the prime variables, the experimental error of the study should be decreased by minimizing soil differences. Here a filled-type lysimeter is indicated, and within this type there still remains room for choice. The lysimeter shell can be filled with soil mixed by layers or with soil homogenized through its entire depth. This choice is again dependent upon the study for which the lysimeter has been designed.

Because the San Dimas lysimeters were installed to compare the water-use and water-yield characteristics of several species of chaparral plants, it was necessary in this installation to combine maximum control over environmental and soil variables and minimum interference with natural growing conditions for the vegetation. For this reason all the lysimeters are of the filled-type, employing homogenized soil, and so located as to be subjected to uniform environmental conditions.

The San Dimas lysimeter installation (fig. 1) consists of five types of lysimeters all located within a rodent- and deer-proof enclosure about 2 acres in area. Uniformity of topography has been emphasized in the location, and all facilitating equipment is so placed as to offer minimum interference to the above-ground environment. A climatic station within the area is equipped to measure all meteorological variables that are suspected of having an influence upon the study. The several groups of lysimeters are surrounded by buffer areas. Lysimeters and their buffer areas receive the same treatment so that the lysimeters, in effect, are sampling areas of uniform treatment. This prevents the border plants from affecting the measured lysimeters themselves.

THE LARGE LYSIMETERS

The large lysimeters form the master group, the others having been installed either to get measurements that could not be made in the large ones or to aid in the application of lysimeter results to natural field conditions. The large lysimeters (figs. 2 and 3) are 26 contiguous concrete tanks, each 10.5 feet by 20.8 feet in horizontal dimensions and 6 feet deep. Each lysimeter holds approximately 64 tons, dry weight, of uniformly mixed stock soil. All concrete surfaces have been coated with a waterproof phenolic resin paint to minimize reaction between the concrete and the plant roots or soil. Each lysimeter has a surface and bottom slope of 5 percent on its long axis, enough to insure adequate surface drainage without introducing slope as a factor in the study. Metal troughs cover the walls between adjacent lysimeters. These troughs can be used to measure the rain falling through the vegetation crowns, that is: rain less interception and stemflow. Surface runoff is collected in a trough extending across the lower end of the soil surface, while seepage drains from the soil through a perforated plate that lies across the lower edge of the soil block. Rain, runoff, and seepage are measured separately for each lysimeter in collector tanks located in a tunnel adjacent to the lysimeter line. Water stage transmitters (1) mounted on the collector tanks in the tunnels are connected to strip-chart recorders which record the rates of rain, runoff, and seepage. This automatic recording is important, for rate measurements are more valuable than measurements of volume in any study involving soil moisture movement.

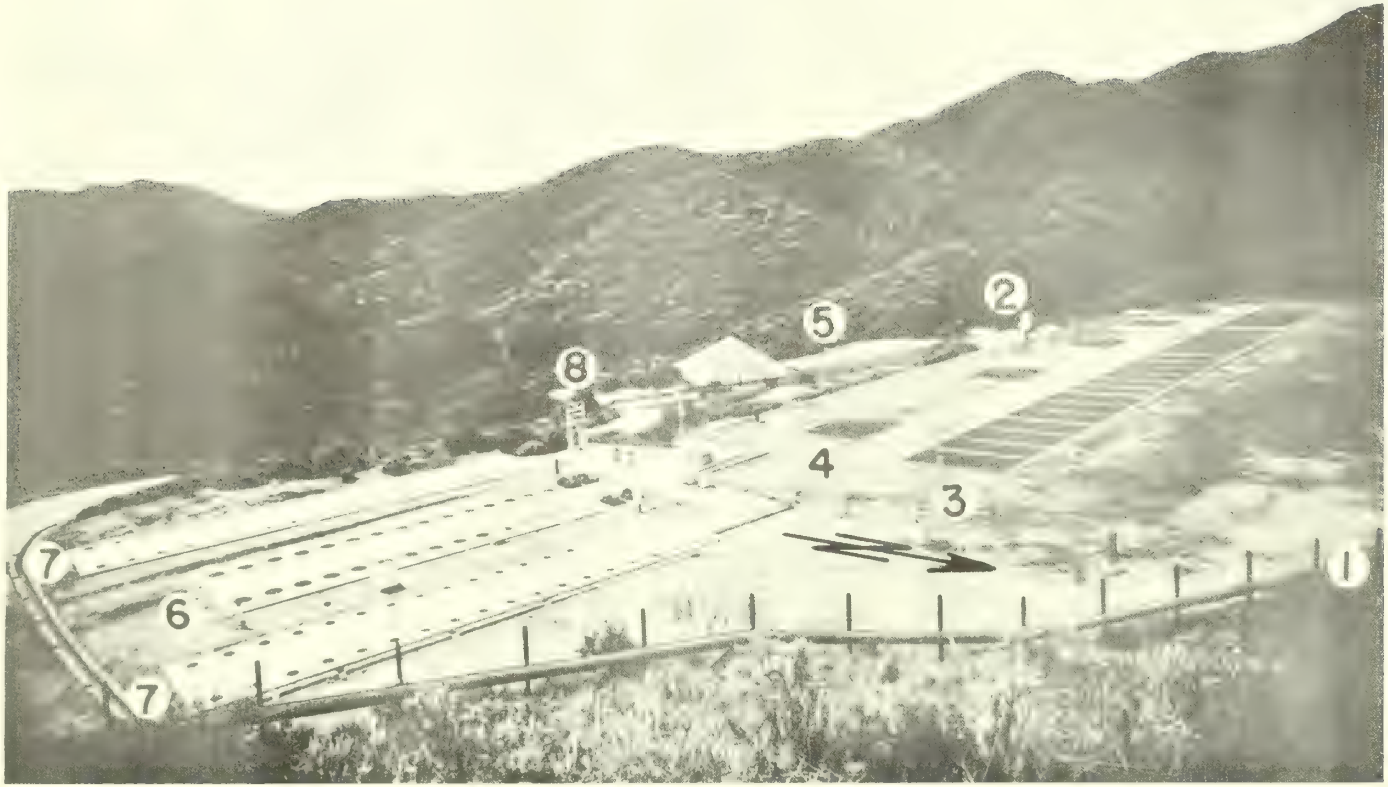


Figure 1.—The San Dimas lysimeter installation. 1. Rodent-and deer-proof fence: 2. climatic station; 3. line of large lysimeters; 4. line of "unconfined lysimeters"; 5. line of root study lysimeters; 6. lines of medium weighing lysimeters; 7. lines of small weighing lysimeters; 8. weighing crane.

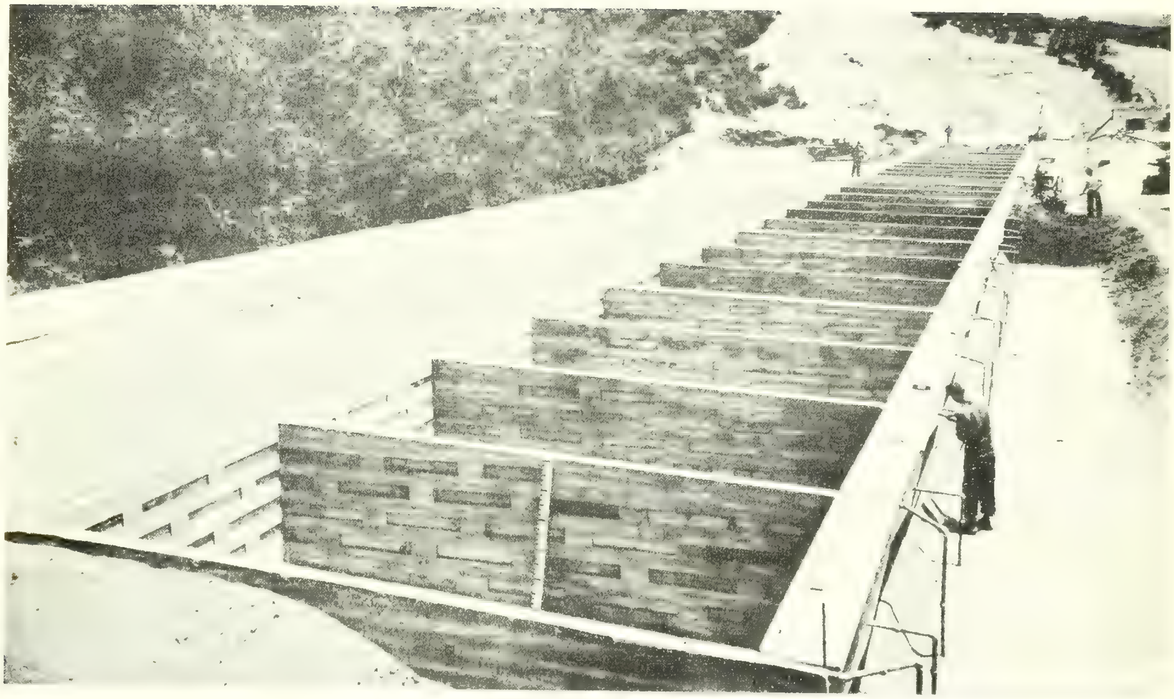
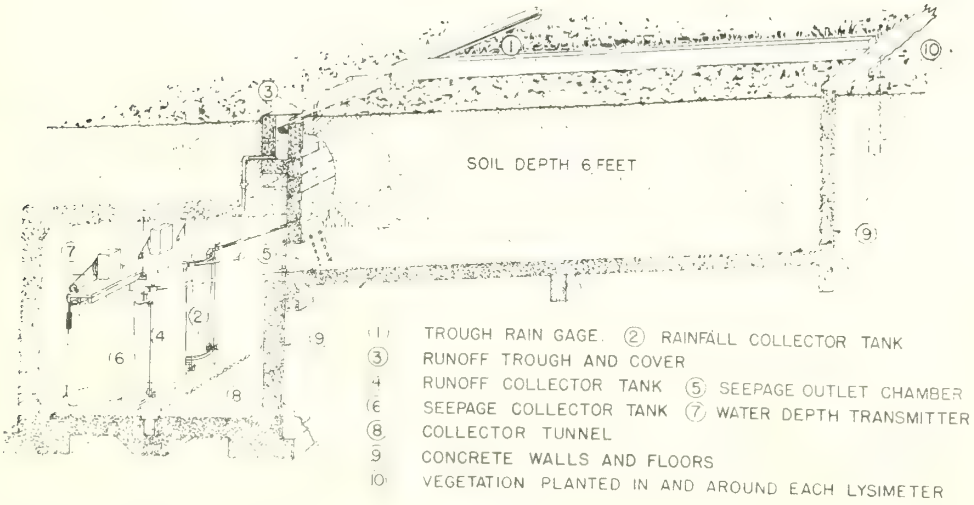


Figure 2.—The large lysimeters before filling. Rain and runoff pipes are shown leading into roof of collector tunnel.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SOIL DEPTH 6 FEET
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① TROUGH RAIN GAGE. ② RAINFALL COLLECTOR TANK
③ RUNOFF TROUGH AND COVER
④ RUNOFF COLLECTOR TANK ⑤ SEEPAGE OUTLET CHAMBER
⑥ SEEPAGE COLLECTOR TANK ⑦ WATER DEPTH TRANSMITTER
⑧ COLLECTOR TUNNEL
⑨ CONCRETE WALLS AND FLOORS
⑩ VEGETATION PLANTED IN AND AROUND EACH LYSIMETER

Figure 3.—Diagram of a single large lysimeter. Surface area 5 milacres (10½ by 21 feet).

THE MEDIUM AND SMALL LYSIMETERS

The large lysimeters provide absolute control of surface runoff, seepage, and root distribution, on a scale large enough to permit a close approximation of natural plant growth conditions. They were not designed, however, for the direct measurement of evaporation and transpiration. For this purpose two types of cylindrical, galvanized iron lysimeters were installed. Of these the medium lysimeters, holding an average of 1600 pounds of soil (fig. 4), have a surface area of 750 square inches and are 40 inches deep. They are large enough to support several perennial plants. The small lysimeters (fig. 5) hold an average of 400 pounds of soil, are 250 square inches in area and 24 inches deep. They were intended for measurement of the water use of single plants grown under artifically controlled soil moisture conditions. Lysimeters of both types rest on pedestals placed in the bottom of concrete-lined trenches so that the soil surfaces of the lysimeters are exposed at ground level. The spaces between the lysimeters are covered with wooden collars, leaving only the soil surfaces exposed to the atmosphere.

The medium lysimeters are equipped for the measurement of runoff and seepage, but the small lysimeters are not. Periodic weighing of both medium and small lysimeters is accomplished by use of a crane scale hung from a wheeled derrick. Evaporation and transpiration losses of soil water can be calculated from repeated weighings.

Thirty medium and seventy-two small lysimeters have been constructed, so that ample replications can be made of plant species growing in the large lysimeters.

THE UNCONFINED LYSIMETERS

As a result of the artifical environment imposed upon plants confined in lysimeters, some transition is needed between enclosed blocks of soil and natural soil conditions in the field. This requires the determination of a relation between the water economy of plants growing in confined blocks of uniform soil and that of the same plants growing in the same kind of soil with the confining walls removed. To accomplish this five pits, each 17½ feet square and 7 feet deep, were dug just south of the large lysimeter line. All pits were refilled with stock lysimeter soil. On the surface of each refilled pit was laid out a sheet-metal-bordered plot from which surface runoff can be collected and measured. Each plot is 7.5 feet wide and 14.6 feet long. The upper and lateral edges of the plot are formed of half-buried strips of 12-inch wide galvanized iron. A galvanized iron trough laid across the lower end intercepts surface runoff, which is then conducted to a collector tank. Water-stage transmitters provide measurements of runoff rates.

Each block of soil thus equipped is called an unconfined lysimeter (fig. 7). The soil from which measurements are taken is surrounded on sides and bottom by the same kind of soil. The depth of the unconfined lysimeter soil is considered to be 6 feet, so that a 1-foot thick soil layer lies beneath it.

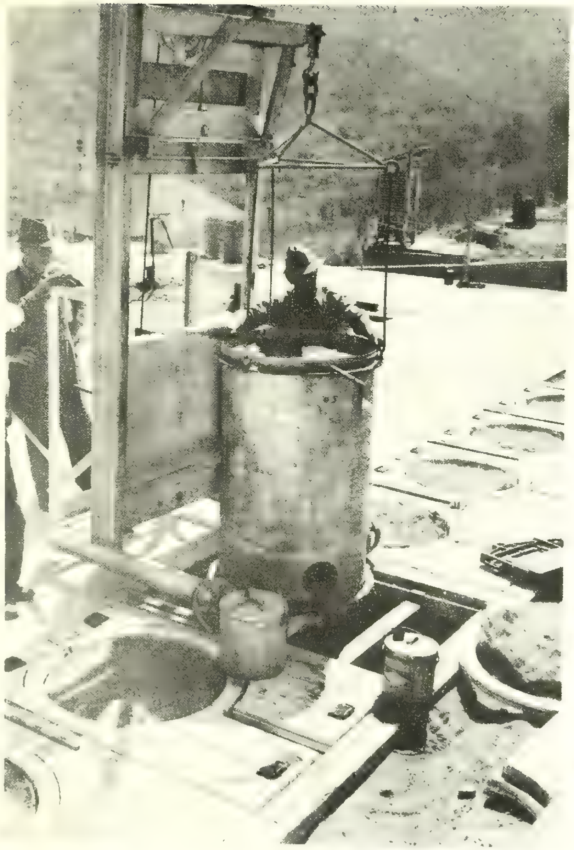

Figure 4.—Medium lysimeters, suspended on weighing crane and in trench. Seepage and runoff collector tanks and weighing scale alsoshown. Excelsior mats protect the soil surface from erosion.

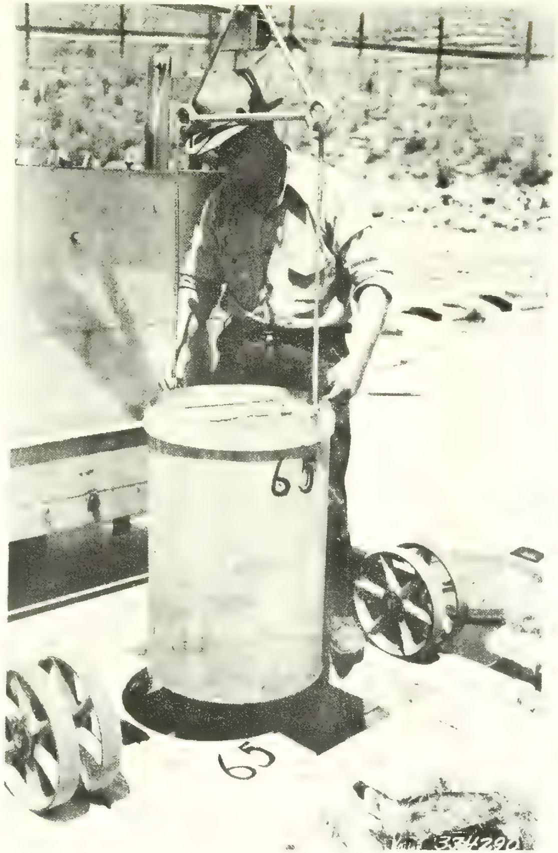

Figure 5.—Small lysimeter hanging on weighing crane.

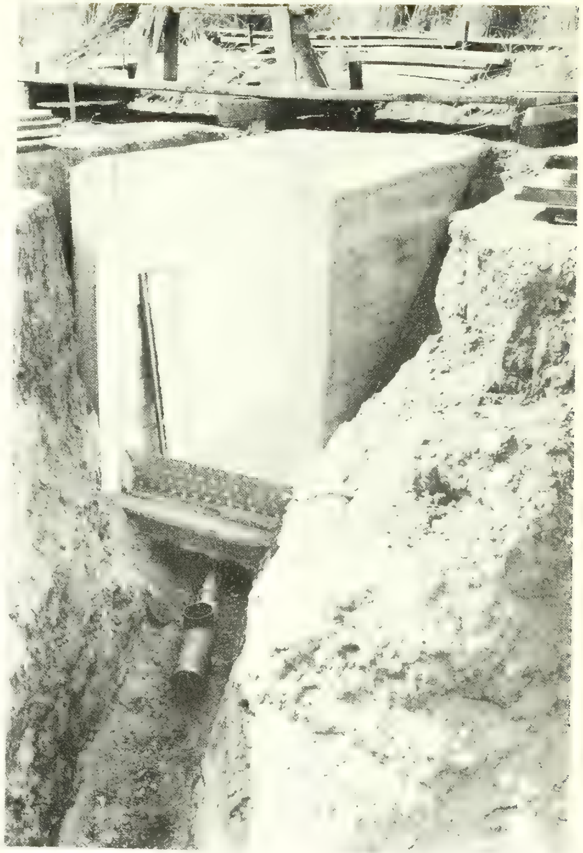

Figure 6.—Unfilled root-study lysimeter with plank wall removed. Perforated metal seepage plate and seepage pipe shown at bottom of lysimeter.

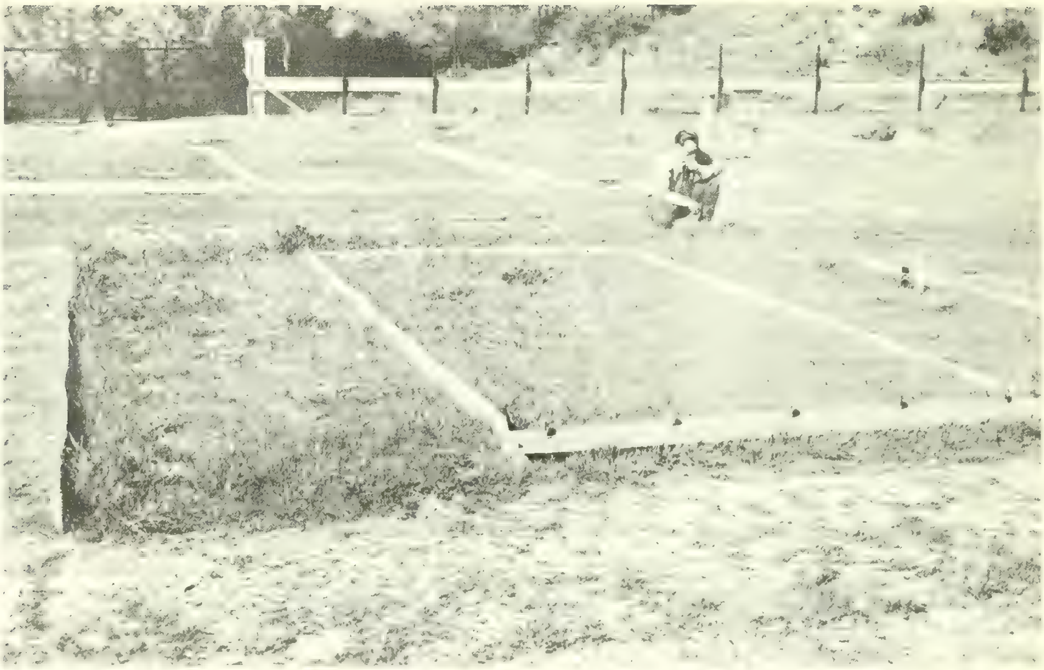

Figure 7.—Surface of an "unconfined lysimeter" showing runoff plot placed within border strip of filled soil.

No direct measurement of seepage through the "bottom" of this type of lysimeter can be made but there are instruments by which the amount and rate of seepage can be calculated. Richards, Russell, and Neal (5) have demonstrated the usefulness of tensiometers for indicating the direction of water movement in the soil. One unconfined lysimeter has been equipped with tensiometers which are serving satisfactorily as seepage detectors. Periodic soil moisture sampling, coupled with tensiometer measurements that show the direction of soil water movement, can be used to calculate the amount of seepage through the unconfined soil blocks.

The lack of a soil/air seepage interface in the unconfined lysimeter eliminates the abnormal moisture conditions found in the deeper levels of confined lysimeters, and thus provides more nearly natural growing conditions for the vegetation being studied. At the same time, however, the substitution of calculated for measured seepage and the impossibility of confining roots to the controlled soil block will detract somewhat from accurate measurement of vegetation water economy in these lysimeters.

THE ROOT-STUDY LYSIMETERS

The root distribution of plants grown in enclosed soil blocks is to be studied in five specially designed lysimeters. These root-study lysimeters are concrete boxes, similar in shape and slope to the large lysimeters (fig. 6). Their soil depth is 6 feet, identical with that in the large lysimeters, but in horizontal dimensions they are only 4 by 6 feet. Their lower end walls are made of redwood planks, fitted so that they can be removed for observation of soil and roots. These lysimeters are not equipped for measurement of runoff or seepage, but as will be noted in the photograph, seepage water is caused to drain from the soil blocks through a perforated plate similar to that used in the large lysimeter. For this reason soil moisture conditions in them should be like those in the large lysimeters. The measurements planned for these lysimeters are related only to plant growth. After plants have grown in them for a sufficient length of time the redwood walls will be removed and the soil washed out, exposing the plant roots for detailed study of their distribution.

THE LYSIMETER SOIL

All lysimeters of the San Dimas installation have been filled with the same kind of soil: a reddish sandy clay loam developed residually at the lysimeter site from dioritic rock of the San Gabriel formation. This soil is probably rather closely related to the Fallbrook soil series. It is similar to soils found elsewhere within the San Dimas Forest on relatively flat areas which have been little dissected in the present erosion cycle. At the lysimeter site it is present in depths exceeding six feet.

Prior to excavation the lysimeter soil showed only a week tendency toward profile development. Its clay content increased slightly to a depth of about 12 inches and then decreased progressively with greater depth. This was reflected in its moisture equivalent, which increased from 18.3 percent in the top 3 inches to 19.1 percent at one foot depth, and then dropped to 15.1 percent at five feet. Apparent soil density increased somewhat with depth, but the only significant difference was between the surface foot (1.4 gm./cc.) and the average of the next four (1.6 gm./cc.)

Soil used to fill the lysimeters was excavated from the site of the large lysimeters and the tunnel. Some 2800 cubic yards taken from the top six feet of this excavation was mixed as thoroughly as possible, passed air-dry through a 3/4-inch screen, and then stored in a bin prepared for this purpose. As the soil was placed for storage, every effort was made to remove all traces of textural variation. The success of the mixing was tested by determining the mechanical analysis of 100 soil samples taken at random from all parts of the storage bin. According to this analysis the soil contained, on the average, 60 percent sand, 25 percent silt, and 15 percent clay. Statistical analysis showed that no significant textural differences existed anywhere in the storage bin. The moisture equivalent of the mixed soil was found to be 19 percent, and the wilting point, 7 percent. Later field tests showed that its field capacity was about 18 percent.

Preliminary experiments in placing and settling the soil were made in walled-off portions of several large lysimeters in order to develop a soil-placement method that would insure the greatest uniformity in density as well as maintain the other already-uniform characteristics of the soil. Several methods of placing and tamping were tried, and analyses were made of the distribution of apparent soil density throughout the resulting soil blocks. The method selected showed a standard deviation of only ± .03 of 1 percent of the average apparent density throughout any one soil block and no significant relation of apparent density to depth. This method consisted of filling the lysimeters by 3-inch-thick soil layers. After sufficient soil was dumped into each lysimeter to consitute a layer, the soil was spread evenly, and then its entire surface was chopped through with a flat-bladed spade. The chopping jarred the soil into close aggregation without introducing the compression zones that usually result from the use of blunt tamping tools.

The success of the soil-placement method is shown by the results of filling the large lysimeters. All soil going into the lysimeters was weighed and sampled for moisture so that the dry weight of each lysimeter soil block could be calculated. At the time they were filled, the average dry weight of soil in the 26 large lysimeters was 137,379 pounds, the standard deviation was only one-half of one percent of this weight, and the extreme range in weight was less than 2 percent. This placed the mean apparent density of soil in the large lysimeters at 1.44 gm/cc. at the time of filling.

The soil in the pits which hold the unconfined lysimeters, likewise, was satisfyingly uniform. Although each of these pits contains nearly twice as much soil as a large lysimeter, their average apparent density was 1.45 gm/cc. at the time of filling; the range of density through the 5 soil blocks was less than 2 percent. The soil in the pits of the unconfined lysimeters is therefore considered to be the same, in all respects, as that in the large lysimeters.

The large and unconfined lysimeters were over-filled 12 inches in order to allow for soil settling during the first few years of exposure to the elements. Annual surveys of the soil surfaces showed that 70 percent of the total settling took place during the first year of exposure; that is, as a result of the first wetting and drying of the soil blocks. By 1940, three years after their first exposure, settling had decreased to a negligible amount. The average settling up to this time had totaled about 6 inches. In the fall of 1940, therefore, the remaining overfill soil was removed and the final lysimeter depth of 6 feet was established. At this time the average dry weight of soil in the large lysimeters was found to be 127,191 pounds, and that of the pits of the unconfined lysimeters, 206,012 pounds. This established their average apparent densities at 1.57 and 1.55 gm/cc., respectively. Soil settling had brought about an increase in apparent soil density of 8.3 percent over the three-year period.

The medium and small lysimeters were filled with soil to the level of their runoff lips, using the procedure described above. In 1940 enough fresh soil was added to compensate for settling and to bring their soil surfaces once more to this level. The root-study lysimeters were filled in the same manner as the large ones. Their soil depths were also adjusted to 6 feet in 1940.

EVAPORATION AND TRANSPIRATION MEASUREMENTS

The measurement of runoff and seepage leaves one phase of the water cycle measured only indirectly in the large and "unconfined" lysimeters. This is the evaporation-transpiration water losses which were to be determined by repeated weighings of the medium and small lysimeters, as has already been explained. Early in the lysimeter study it appeared desirable to study methods of making these measurements directly in the large and "unconfined" lysimeters instead of assuming some relationship to exist between the stationary and the weighed types. Accordingly, periodic soil-moisture sampling was carried on for several years in two of the large and in one of the "unconfined" lysimeters. Despite the desirability of sampling more lysimeters, the large amount of work required and the possibility that sampling might alter lysimeter characteristics has prevented further expansion. The need for some "in situ" soil-moisture indicator stimulated research into the development of an electrical soil-moisture meter. An instrument has been developed on the Experimental Forest which may provide a solution to this problem (2). Soil and measuring units of this instrument were manufactured in 1947, and a test installation in the lysimeters is planned for 1948.

THE LYSIMETER RESEARCH PROGRAM

The research plan for the lysimeters includes three periods of study. During the first period, 1937-40, the soil surfaces were maintained free of vegetation and protected from erosion by a mulch of excelsior. Measurements of rain, runoff, and seepage were made, so that inconsistencies in reaction between the several lysimeters of each type could be discerned. The principal purpose of this preliminary period, however, was to permit the completion of soil settling.

After the removal of surplus soil from the lysimeters in 1940, an annual grass (*Bromus mollis*) was planted to start the second research period. The use of this species, which has considerable importance in the range lands of central California, was to have a twofold purpose: (1) it would provide an opportunity to detect consistent or erratic differences between lysimeters under a vegetation made as uniform as possible, and (2) information would be obtained relative to the life cycle of the grass and its water economy. After the first seeding, the grass was allowed to seed itself naturally both inside the lysimeters and in the border strips around them.

During the grass-cover period one of the large lysimeters and four each of the medium and small tanks were maintained bare of all vegetation. This made possible a comparison of the water regime under bare and under grass-covered surfaces. There was a highly significant difference in erosion between the two treatments on the large lysimeters. The bare soil developed an erosion pavement and suffered a considerable loss of fine material, while the dense grass cover on the planted lysimeters prevented erosion almost completely. The infiltration rate of the grass-covered lysimeters increased since the first seeding by a small but significant amount, while that of the bare large one remained at the very low value which characterized all the lysimeters during the preliminary, excelsior-surfaced period.

The final research period started in 1946, when the grass cover was replaced by the chaparral species whose water economy the lysimeters were planned to measure. The planting plan of the lysimeters is presented in Table 1. Five species of native chaparral plants have been used: *Eriogonum fasiculatum*, *Adenostoma fasiculatum*, *Ceanothus crassifolius*, *Quercus dumosa*, and *Pinus coulteri*. A single planting of each species occupies five contiguous large lysimeters, one unconfined lysimeter, and the buffer areas around them, which extend 20 feet north and 50 feet south of the edges of the large lysimeter line. One of the large lysimeters is still maintained with a bare soil surface.

The root study lysimeters and their buffer area have also been planted, one to each of the study species. The medium and small lysimeters remain unplanted in 1947. As is reported in Part 2 of this paper, inconsistencies in reaction have been observed between the weighing-type lysimeters and the others. Until certain changes in design have been made in them the medium and small lysimeters will remain withdrawn from use in the lysimeter study.

Table 1.- Planting plan of San Dimas lysimeters

Large lysimeter No.	Species	Unconfined lysimeter No.
1	Bare	
2	Eriogonum fasiculatum (border)	
3,4,5	" " (controlled)	A
6	" " (border)	
7	Adenostoma fasiculatum (border)	
8, 9, 10	" " (controlled)	B
11	" " (border)	
12	Ceanothus crassifolius (border)	
13, 14, 15	" " (controlled)	C
16	" " (border)	
17	Quercus dumosa (border)	
18, 19, 20	" " (controlled)	D
21	" " (border)	
22	Pinus coulteri (border)	
23, 24, 25, 26	" " (controlled)	E

SUMMARY

The San Dimas lysimeters were established for the purpose of comparing the water economy of a number of chaparral plant species that are important in the management of southern California mountain watersheds. The installation includes five types of lysimeters and a climatic station located on an area of uniform topography and enclosed in a rodent-proof and deer-proof fence. The same kind of soil has been used and uniformly placed in all the lysimeters in order to minimize soil variability. Rain, runoff, and seepage are measured, and weighing or periodic soil moisture sampling is used to study evaporative water losses.

The lysimeters were installed in 1937 and their soil settling was measured under excelsior-covered surfaces from 1937 to 1940. In 1940 the originally overfilled soil blocks were cut down to their final depths and all but a few tanks were seeded with Bromus mollis, thus initiating the second phase of the study. The final phase of research was entered in 1946 with the conversion of the grass cover to stands of the several chaparral species whose water economy is to be studied.

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PART 2 -- THE RELATIVE PERFORMANCE OF FOUR TYPES OF LYSIMETERS[1]

The purpose of this paper is to compare certain data obtained from four types of lysimeters included in the San Dimas installation, to learn whether it is possible to use one type of lysimeter to provide data to supplement those obtained in another type

A number of investigators have suggested that simple or even consistent relations might not exist between the moisture conditions of different kinds of lysimeters. In 1913 Willard and Humbard (10)[2] noted that more water passed through a four-foot depth of undisturbed field soil than through a lysimeter having the same soil depth and treatment. In 1917 Alway and McDole (2) found that a fine soil underlain by sand retained more water against drainage than it did when this textural layering was not present. These studies introduced the concept of the interface effect: the incomplete drainage of enclosed lysimeters caused by the requirement that seepage water must pass across a soil-over-air interface in order to leave the soil. Aderkas (1) found that shallow lysimeters filled with sand held more water per unit of depth than did deeper ones. This he attributed to the interface effect and he noted that, as a result, increased evaporation corresponded with a decrease in lysimeter soil depth. Neal, Richards, and Russell (7) buried tensiometers in confined lysimeters and found that the soil in the bottom of the lysimeter must be nearly saturated before seepage would occur.

Most early investigators who made use of lysimeters expressed no concern over the reliability or applicability of their data. The literature shows that these workers almost always assumed that their lysimeters represented an approach sufficiently close to natural conditions to satisfy them, at least with respect to the factors under investigation. Recently, however, there have been suggestions that moisture conditions in enclosed soil blocks might be sufficiently different from conditions in the field to justify a critical examination of the lysimeters themselves Thus Wallihan (9) studied the influence of the soil/air seepage interface by inserting a tensiometer cup in the base of a small lysimeter and maintaining a tension of 10 cm. Hg on the soil water at that level. He found significant differences in evaporation, seepage, and plant growth between this lysimeter and one in which no seepage tension was applied. In their excellent survey of lysimeters, Kohnke, Dreibelbis, and Davidson (6) stress the importance of duplicating natural environmental conditions in enclosed soil blocks if the data obtained from them are to have field application. They mention the desirability of measuring, not only the average moisture content of the lysimeter soil, but also the distribution of moisture within the soil block.

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[1] The graphical analysis included in this paper was performed by N. O. Broughton of Civilian Public Service Camp #76, Glendora, California, whose assistance is gratefully acknowldged .

[2] Numbers in parentheses refer to References, page 33.

In 1940 and 1941 the American Geophysical Union Committee on Evaporation and Transpiration devoted its annual reports (4, 5) almost exclusively to discussions of the usefulness of water utilization data obtained from lysimeters. Although many excellent discussions and suggestions appear in these reports, there is a marked lack of reference to specific studies of lysimeter behavior. Most of the discussions suggest that lysimeters do not provide data comparable with those obtained from natural soils, and both reports emphasize the necessity for establishing natural conditions in lysimeters before comparable results can be obtained. Summarizing the replies to the questionnaire which formed the basis of the 1941 report Kittredge stated: "the point is emphasized by several that the transpiration from plants in containers would be the same as that without, if all the conditions and particularly the soil moisture, were the same within as without ... If the conditions are not thus identical, the application of figures for estimation of transpiration over large areas forthwith becomes subject to uncertainty "

The wide response to the lysimeter questionnaires indicates the interest shown by research men in the problems connected with their use. The lack of unanimity upon many points demonstrates the need for studies designed specifically to investigate the behavior of lysimeters. The San Dimas lysimeter installation provides an opportunity for such a study since it includes several lysimeter types differing in design but identical as to environment, soil, and vegetation. Information concerning this installation was presented in Part 1.

THE DATA

Since the lysimeters of the San Dimas installation were designed to study the water economy of plants, a comparison of water content of the several lysimeter types was made the primary basis for the study of their behavior.

The small and medium lysimeters were weighed weekly during the greater part of each year, thus providing direct periodic measures of their water content. From 1937 to 1940 all 72 small and all 30 medium lysimeters were maintained free of vegetation. After 1940 four tanks of each type were kept bare while the remainder supported reasonably uniform stands of annual grass (Bromus mollis). The soil water contents used in this analysis are average values for each date of determination, for all lysimeters having the same treatment. Soil samples were obtained twice during the course of this study from each set of the weighing lysimeters. Soil was collected by 3-inch layers so that its moisture content could be related to soil depth and lysimeter treatment.

The large and unconfined lysimeters received the same sequence of treatments as did those just described. All the unconfined and all but one of the large lysimeters were planted to Bromus mollis in 1940. The remaining large lysimeter was maintained bare of vegetation throughout this period.

The water content of the large and unconfined lysimeters was determined by periodic moisture sampling during the last two years of this study. Weekly or bi-weekly samplings were made in one bare and one grass-covered large tank and in one of the grass-covered unconfined lysimeters. Soil water content was determined by 6-inch-thick soil layers to a depth of 6 feet. Total water contents of the lysimeters were calculated from these data for each date of sampling.

The grass yields of all the lysimeters were determined each year after the matured grass was mowed to a uniform stubble height. The dry weight of the grass produced in 1940-41 and 1941-42 in the four types of lysimeters has been utilized to show further the agreement between lysimeter groups.

In analyzing the soil-moisture data the most direct comparisons have been made possible by plotting the average water content of one lysimeter type against that of another type on the same day. By this procedure definite relations demonstrated themselves readily, the general shape of the data envelopes indicated the kind of relation existing between the two variables, and the scatter of the data about the regression line provided an indication of the reliability of the relation. Furthermore, when the plotted data were connected in chronological sequence the relation between corresponding periods or moisture stages could be studied.

Statistical analysis has not been resorted to in this study because the results are believed to be sufficiently well defined without the use of mathematical criteria of reliability. Instead, in those cases showing definite relations the regression line has been used as the means of calculating the water content of one lysimeter type from that of the other. The calculated and measured values have then been plotted on the same chart as a function of time; and the occurrence, magnitude, and direction of differences between the two were studied to indicate the significance of the regression line.

RESULTS OF ANALYSIS

Relation between water content of medium and small lysimeters.

In figure 8 data are presented relating the water contents of the medium and small lysimeters. In Figure 8(A) the average water content of the bare lysimeters has been plotted for the period from March 1938 to October 1942. In Figure 8(B) the same data have been plotted for the grass-covered lysimeters for the period October 1940 to October 1942. The relation in both cases is obviously linear, and the scatter of points is small enough to make the location of the regression line quite definite. Only in the early part of the 1940-41 season (indicated by lines connecting points) do the data show a distinct divergence from the general relation. At the start of this season fresh soil was added to all the lysimeters to make up for the soil settling that had taken place since the tanks were first filled. It is felt that the addition of dry

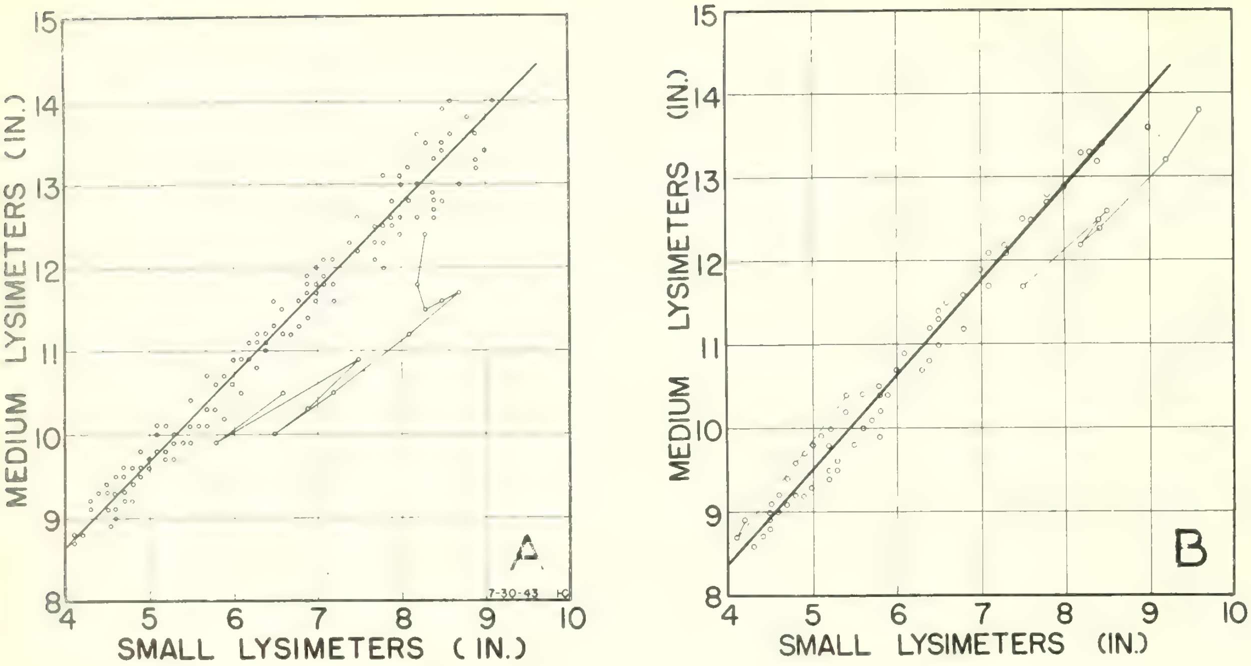


Figure 8.—Relation between water content of medium and small lysimeters; (A) bare soil, 1938-42, (B) grass-covered soil, 1940-42. (Early 1940-41 season data connected by lines.)

soil provided the cause of this divergence. The deeper medium lysimeters required, of course, more soil than did the smaller ones. The following equations describe the regression lines of Figures 8(A) and 8(B):

Bare lysimeters: $M = 1.04S + 4.55$

Grass-covered lysimeters: $M = 1.15S + 3.85$

In these equations M is the water content (inches depth) of the medium and S that of the small lysimeters.

It is apparent that water content is not directly related to soil depth, but that a proportionality factor must also be introduced. It will be noted further that the two equations, one relating bare and the other grass-covered lysimeters, have different constants. This indicates that treatment has an effect on the relative performance of lysimeters of different size and shows that the small lysimeters cannot be considered scale models of the medium ones. Therefore, it is not possible to calculate water use by plants in the medium lysimeters from water use measured in the small lysimeters without first growing the SAME PLANTS IN BOTH LYSIMETERS for a calibration period.

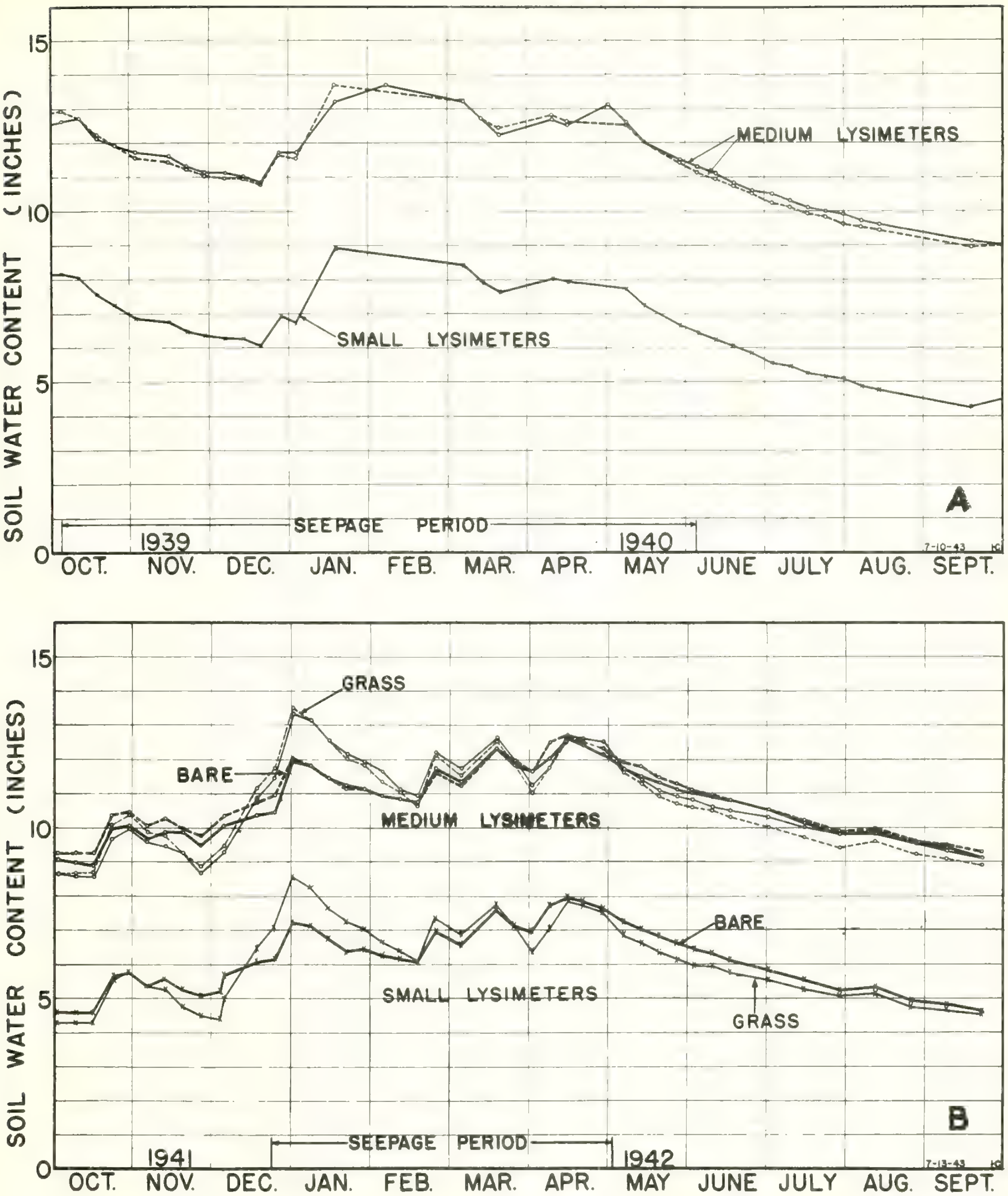


Figure 9.—Annual cycles of soil water content in medium and small lysimeters; (A) 1939-40, (B) 1941-42. Solid lines connect observed points; dashed lines, calculated points. (The same relations are shown during the 1940-41 and 1942-43 seasons.)

In Figure 9 the average measured water contents of the medium and small lysimeters are shown as a function of time for two years of the study. The figure also contains the water-content curve calculated for the medium lysimeters from the equations just presented. The general agreement of calculated and measured values for the medium lysimeters is immediately apparent. Considering the whole period of study, the maximum differences between calculated and measured values are found in the early part of the 1940-41 season, soon after the addition of fresh soil to the lysimeters. The reason for this difference has already been explained. With the exception of this period, the maximum difference is not greater than + 0.3 inch.

It will be noted in Figure 9 that each year the medium lysimeters (both bare and grass-covered) reached their maximum water content at very nearly the same date as did the small ones. During the following period of 3 or 4 months the average water-content of the medium lysimeters was 1.57 times that of the small ones. This corresponds very closely to the ratio of medium to small lysimeters soil depths (1.58 to 1) and thus indicates close agreement between the average maximum moisture contents of the two lysimeter groups.

The average water-content ratio in late summer was 1.98 to 1, showing that more water was lost in the drying period from the small (shorter) lysimeters relative to their depth than from the medium lysimeters. As is shown in Table 2 dry season water losses from the two lysimeter groups were nearly equal. This means that, depth for depth, the small lysimeters lost more water than did the medium lysimeters and, therefore, should have ended the dry season with a lower average soil-moisture content. This has been confirmed by measurement. Soil moisture samples were obtained late in September (the end of the dry season) from the medium and small lysimeters (fig. 10). As was expected the moisture contents of the small lysimeters were lower than those of the medium lysimeters at every depth under both bare and grass-covered surfaces. In view of these findings a consistent relation between the water contents of the two lysimeter groups would seem to depend on both groups being brought to maximum moisture contents (i.e., the establishment of seepage) each year. Because of their shallow depths and the possibility of impounding water upon their surfaces, this condition has been met each year despite a considerable variation in annual rainfall.

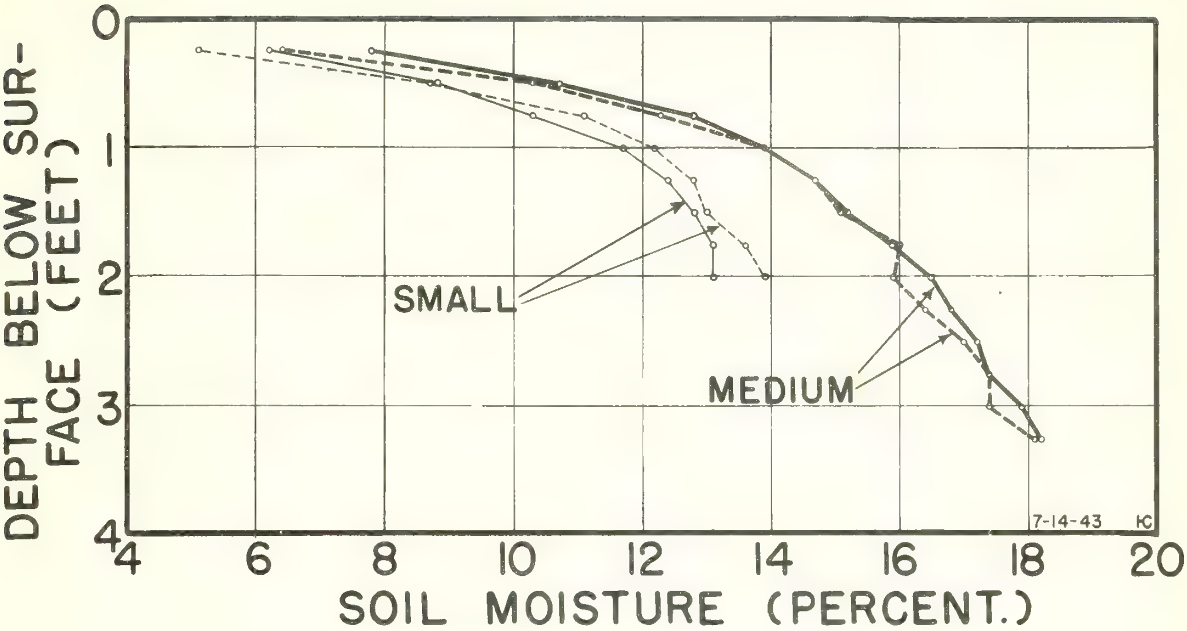


Figure 10.—Soil moisture distribution in medium and small lysimeters at the end of the 1940-41 dry season (9/25/41). Bare lysimeters shown by solid lines, grass-covered by dashed lines.

Table 2.- Dry season water losses from medium and small lysimeters

Year	Season	Evaporation(bare soil)		Evapo-transpiration (grass-covered soil)	
		Medium lysimeters	Small lysimeters	Medium lysimeters	Small lysimeters
		Inches	Inches	Inches	Inches
1938	5/5 -9/28	4.0	4.0	-	
1939	4/1 -9/20	5.3	4.9	-	
1940	5/1 -9/14	4.0	3.7	-	
1941	4/18-9/25	3.6	3.7	4.9	4.2
1942	4/15-9/22	3.5	3.2	3.6	3.3

Relation between water content of large and medium lysimeters maintained bare of vegetation.

Water content data for the total soil depths of the one bare large lysimeter and the average of the bare medium lysimeters over a period of two years have been related in Figure 11. The regression lines fitted to the data show better agreement between water contents of the two lysimeter groups during the dry part of each year than during the rainy part.

It will be observed first that data of the two years do not coincide. The two regression lines are parallel and both lie at such a slope that the coefficient in each equation is unity. The equations relating water content of the lysimeters are as follows:

1940-41 season: Large = medium + 9.41 inches
1941-42 season: Large = medium + 8.05 inches

The significance of the 45° slope of the two lines is not clear in view of the lack of such a relationship between the medium and small lysimeters. The separation of the lines representing the two years may be related to the rainfall characteristics of the two seasons. The 1940-41 rainy season was characterized by a long period of fairly continuous rain and a high seasonal total of 48 inches. The next year was characterized by scattered small showers totaling only 16 inches. In 1940-41 little evaporation occurred during the rainy season, and the rain was sufficient to produce seepage from both lysimeters. During the 1941-42 season most of the added water had been lost by evaporation before the end of the wet season, and soil sampling in the large lysimeters showed no water penetrating more than one foot below the surface. Therefore in the spring of 1941 the bare large lysimeter entered the dry season with a higher water content than it did the following year. The medium lysimeters, on the other hand, produced seepage both years. This was due to the impounding of water on their soil surfaces (the surface runoff outlet cannot be adjusted to drain the soil surface completely), which resulted in greater uptake of water in these lysimeters during the 1941-42 season than in the large lysimeters. The bare medium lysimeters reached very nearly the same maximum water content in both seasons, although this was not the case in the bare large lysimeter (fig. 11(A)).

The data in Figure 11(A) have been connected in chronclogical sequence, demonstrating the wide discrepancy in the early part of the 1940-41 season. Again the disagreement between these data and the general trend can be attributed to soil changes occurring just before that rainy season. At that time (the end of the soil settling period) a layer of overfill soil approximately six inches thick was removed from all the large lysimeters. As a result of the removal of the drier top soil, the large lysimeter entered the rainy season with a higher-than-normal average moisture content, while the addition of dry soil to the top of the medium lysimeters reduced their average moisture content. The influence of this treatment persisted until January 1941, when the bare medium lysimeters had almost reached their maximum water content.

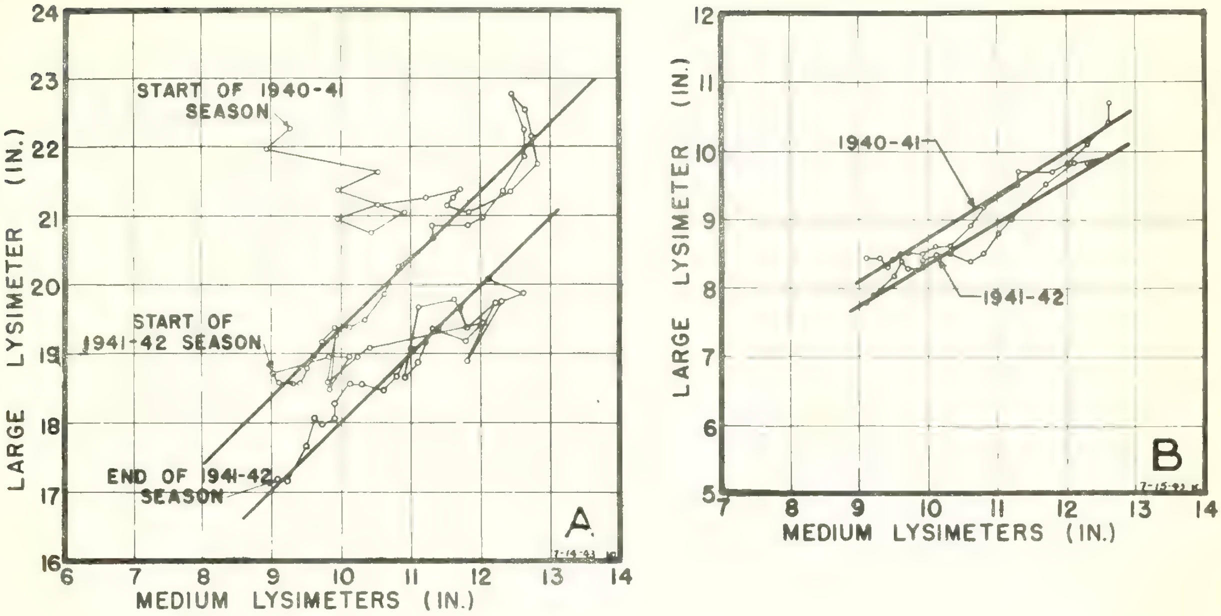


Figure 11.—Relation between water content of bare large and medium lysimeters, 1940-42; (A) Full lysimeter depths, (B) 38-inch soil depths during dry seasons.

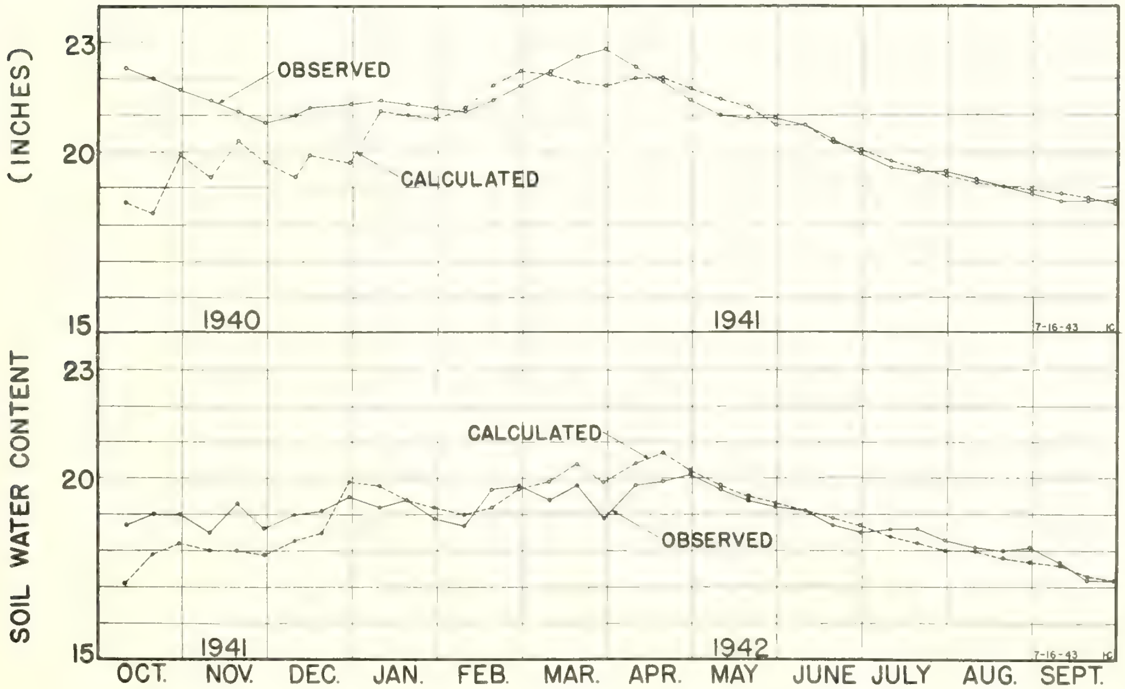


Figure 12.—Observed and calculated soil-water cycles in the bare large lysimeter, 1940-42.

The equal dry-season water losses in the bare medium and large lysimeters are probably something of a coincidence, for all the water lost from the large lysimeters did not come from the top 38 inches of soil corresponding to the medium lysimeter soil-depth. This may be seen by reference to Figure 11(B), in which the water content of the top 38 inches of large-lysimeter soil has been shown in relation to that of the medium lysimeters at corresponding dates. If all the water loss from the large lysimeter had come from above 38 inches depth, the slope of the regression line in this figure would have been equal to that in Figure 11(A). Actually, however, only two-thirds as much water was lost from 38 inches of soil in the large lysimeter as from the corresponding depth of soil in the medium lysimeter. The remaining one-third of the water lost must have come from greater depths in the large lysimeter, so that its evaporation loss during the dry season was equal to that of the medium lysimeters.

The relations derived in Figure 11(A) have been applied in Figure 12, where the observed water content of the bare large lysimeter at any date can be compared with that calculated from the water content of the bare medium lysimeter by the use of the equations given above. The agreement of the two amounts is rather poor during that portion of each year when the soil moisture content is high, but it becomes very good during the drying seasons.

The fundamental difference between these lysimeters seems to arise from the incomplete moisture recharge of the large lysimeters during one of the two years studied, a condition not encountered in the medium lysimeters. It appears probable that both lysimeters would have had closely related water cycles, regardless of their surface areas, if both had had the same soil depth and equal freedom of surface drainage.

Relationship between water contents of large and medium lysimeters supporting a cover of annual grass.

When medium and large lysimeters having a grass cover are compared (fig. 13) the resulting relation is more indefinite than the one between the bare lysimeters. The curved regression line in Figure 13 is based upon all data except that of the early part of the 1940-41 season, which was unique because of the removal of soil from the surface of the large lysimeters. Although a curvilinear relation is indicated, the scatter of the data about the regression line detracts from the significance of its location and shape. The relation is not improved by a comparison of the water contents of the 38-inch deep soil layers alone. Consequently these data have not been included here.

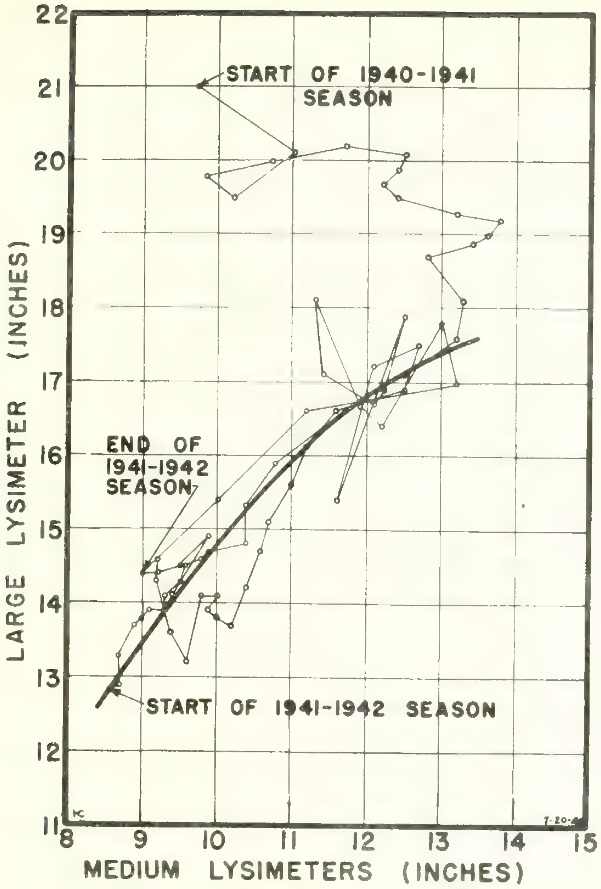
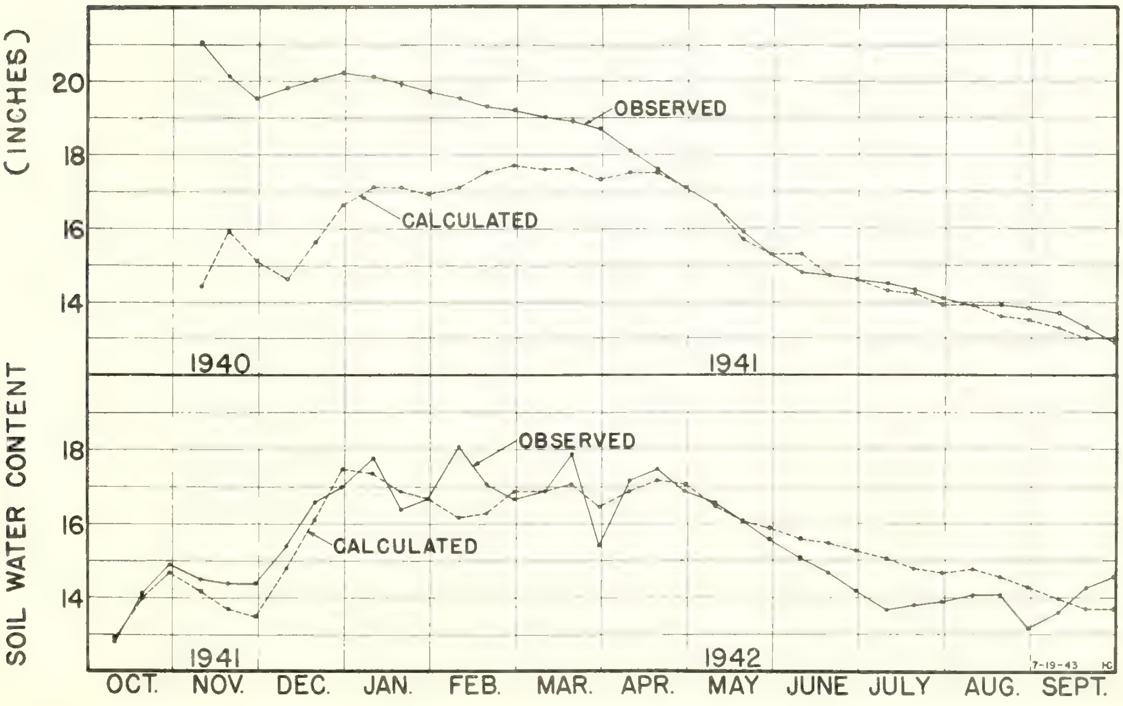


Figure 13.—Relation between water content of grass-covered large and medium lysimeters, 1940-42.

Figure 14.—Observed and calculated soil-water cycles in grass-covered large lysimeters, 1940-42.



Application of the regression curve to the observed water-content data is made in Figure 14. As was to be expected, the early part of the 1940 41 season shows poor agreement between observed and calculated values. The later part of this season shows good general agreement. The next season exhibits fair agreement during the earlier part of the year, but the water-loss rates measured in the large lysimeter during the later part of the year are considerably greater than those indicated by the calculated water-content line. These results indicate that the grass-covered medium and large lysimeters are comparable as to their water losses only in the most general way.

Reasons for the lack of consistent relationships between these lysimeters may be traced to the yield of grass (to be discussed later), and to their uptake and storage of water. Differences in water absorption between the large and medium lysimeters have already been explained. Summer water losses from the grass-covered large lysimeters were 5.6 inches in 1941 and 4.3 inches in 1942, compared with losses of 4.9 inches and 3.6 inches respectively from the medium lysimeters. It follows that, although only the grass-covered medium lysimeters produced seepage each year, they lost less water by evaporation than did the large ones. The greater soil depth and better conditions for root development in the large lysimeters (see discussion of grass yield) appear to have resulted in heavier grass yield with increased evapo-transpirational water use relative to that of the medium lysimeters. On the basis of this analysis it cannot be said that a unique relation does exist or would be expected to exist between the medium and large grass-covered lysimeters.

Relation between water content of large and unconfined lysimeters, and between that of medium and unconfined lysimeters

The water contents of the grass-covered large lysimeters are compared in Figure 15 with the water content of the grass-covered unconfined lysimeters at corresponding dates. Figure 16 presents the same relation between the medium and unconfined lysimeters. Both graphs show a wide scatter of points and no consistent relation through the two-year period. Therefore, no attempt has been made to establish a regression line relating these lysimeters. Although both reached approximately the same maximum values in the 1940-41 season, the rate of water loss from the unconfined lysimeters during the early summer was by far the greater. The low rainfall of the next season did not permit complete recharge of moisture storage in either lysimeter, and the rates of water loss from the two lysimeters during the early summer of 1942 were nearly equal. However, even under these conditions the soil water contents of the two lysimeter groups cannot be considered to be uniquely related. A comparison of Figure 17 with Figure 9 shows also the lack of a unique relationship between unconfined and medium lysimeters planted with the same kind of vegetation.

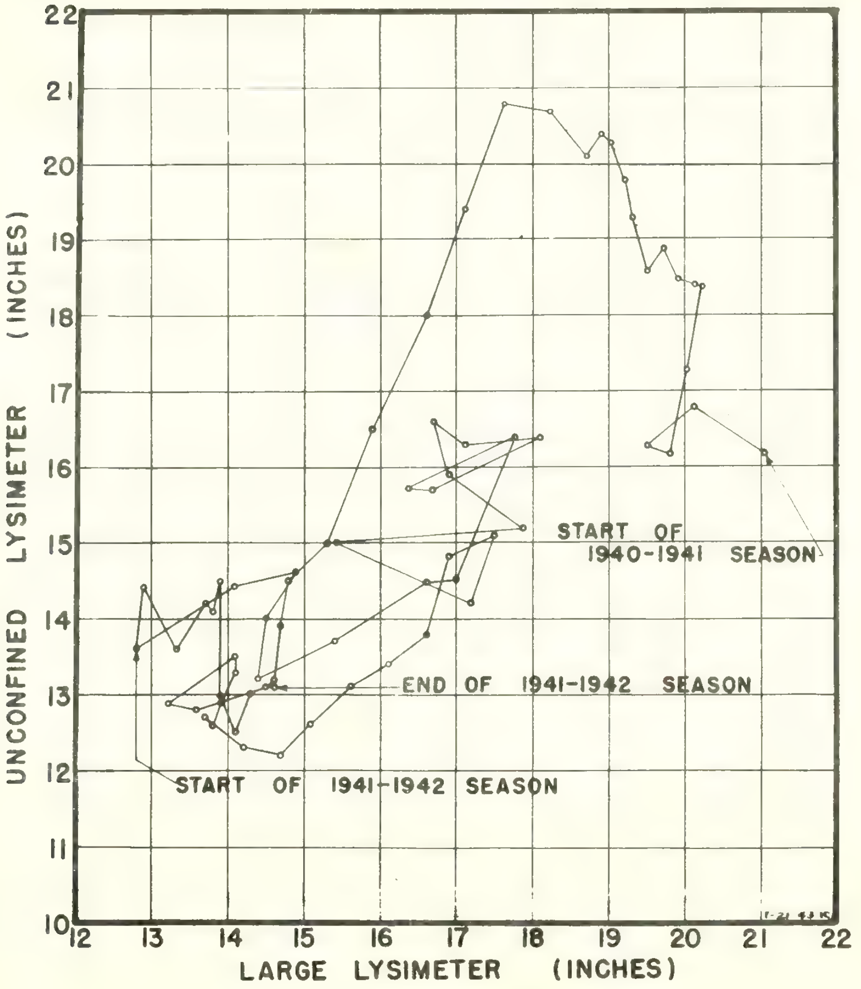


Figure 15.—Relation between water content of grass-covered unconfined and large lysimeters, 1940-42.

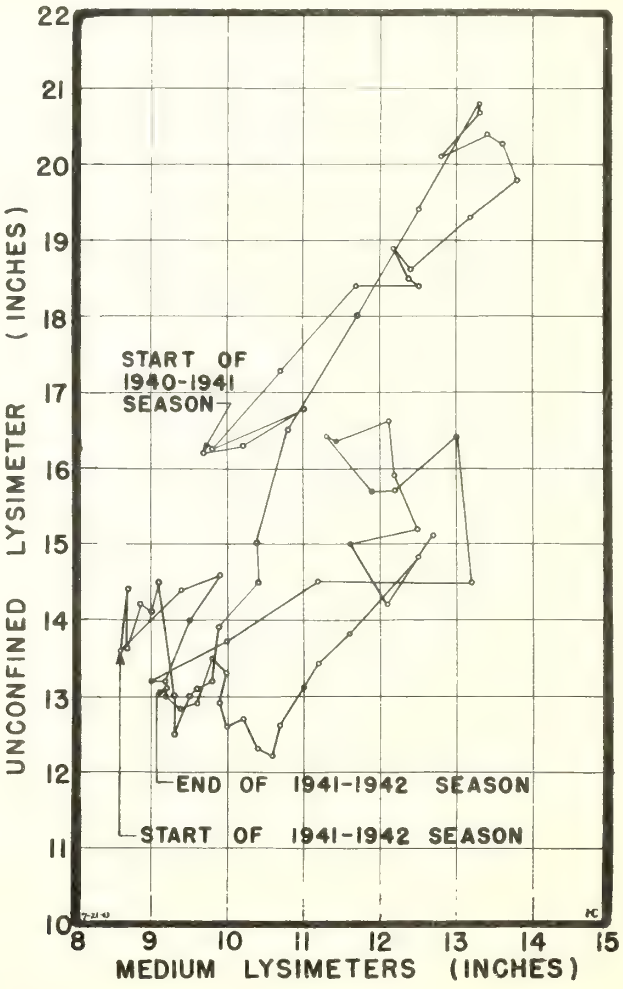


Figure 16.—Relation between water content of grass-covered unconfined and medium lysimeters, 1940-42.

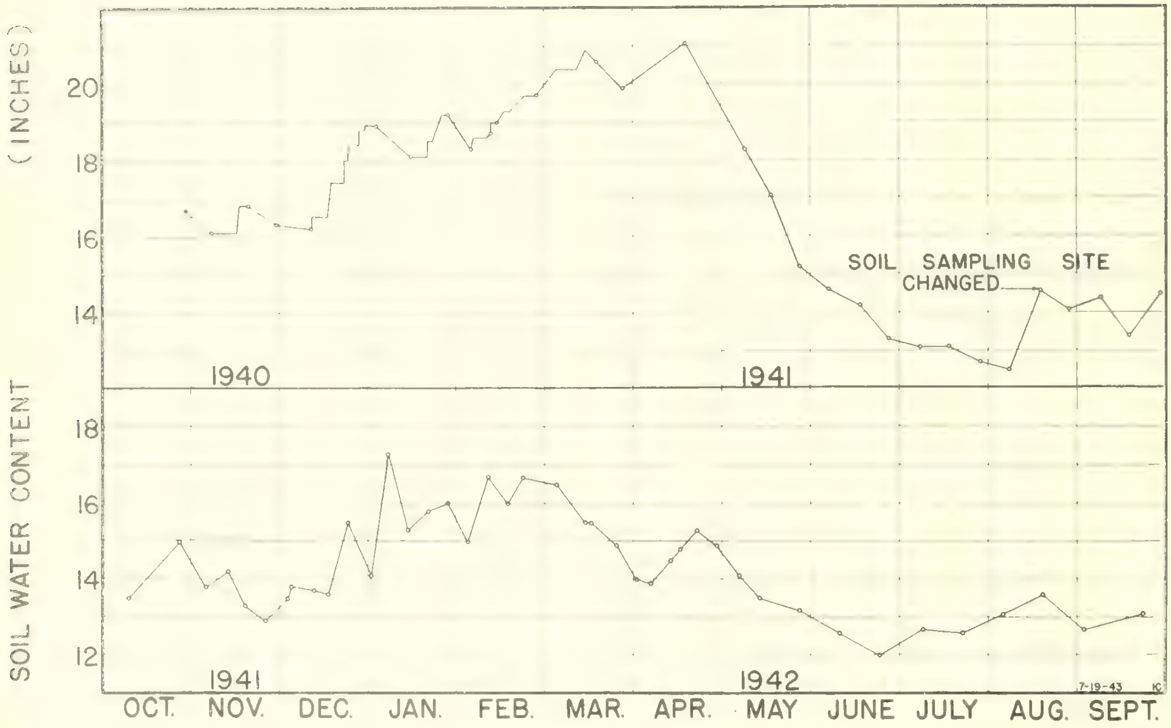


Figure 17.—Observed soil-water cycles in grass-covered unconfined lysimeter, 1940-42.

The lack of a soil/air interface at the base of the unconfined lysimeter introduces a fundamental difference between this kind of lysimeter and the enclosed soil blocks represented by the large, medium, and small lysimeters. Seepage water in the large lysimeters can be lost from the soil only by its passage into the drain pipe at the lower edge of the soil block. Hence, seepage from these lysimeters continues long after tensiometer measurements in the bottom of the unconfined soil blocks have shown that downward movement has ceased. Furthermore, tensiometers in the soil at the base of the large lysimeters show that the soil moisture tension there must equal zero before seepage will start, while tensions of 3 to 5 cm. of mercury have been measured regularly by tensiometers at the base of the unconfined lysimeters during their seepage period.

These last observations indicate that the maximum soil moistures in the unconfined lysimeters are definitely below saturation while those near the base of the large lysimeters are representative of a saturated condition. The resulting better aeration of the unconfined lysimeters may be the cause of their greater crop yield (see grass yield discussion) and evapo-transpiration water loss in the 1940-41 season, as shown in Table 3. The reversal shown in this table for the 1941-42 season is probably due to the lower soil moisture contents of both these lysimeters (resulting in better soil aeration) caused by the deficient and sporadic rainfall of this year.

The conclusion must be drawn that the unconfined lysimeters bear no consistent relation to the other lysimeter groups insofar as their water contents and water losses are concerned.

Table 3.- Evapo-transpiration water loss during the dry seasons of 1941 and 1942, in the large and unconfined lysimeters

Year	Season	Water loss Large lysimeter	Water loss Unconfined lysimeter
		Inches	Inches
1940-41	April to October	5.6	9.0
1941-42	May to September	4.3	2.4

Grass yields in the lysimeter groups.

The annual harvest of grass (Bromus mollis) on the lysimeters made it possible to obtain direct comparisons of grass yield per unit area of lysimeter surface. These data demonstrate the striking differences in growing conditions in the several lysimeter groups (table 4). The fairly good agreement between large and unconfined lysimeter yields stands in marked contrast to the lower yields from the shallower soil tanks. That the differences are not caused by limited water supply in the smaller tanks has been established by soil moisture determinations made in the lysimeters after the grass had matured and dried. In no case did the average moisture content approach the wilting point of the soil. Although scarcity of water was not the cause of lower grass yields in the shallower lysimeters, it appears possible that periods of excess water during the growing season may have been. The small and medium lysimeters produced seepage during 1941 and 1942 and free water was often observed on the soil surfaces of the small lysimeters after periods of rain. It appears probable that, owing to the interface conditions at the base of the soil columns, the small lysimeters may be nearly saturated through the greater part of their 24-inch depth before seepage takes place. By the same token the medium and large lysimeters would be saturated to an equal height above the seepage plane. This would provide a greater depth of aerated soil with increasing depth of lysimeter. Thus, the deeper the soil block, under these drainage conditions, the better would be the average growing condition for plants.

Table 4.--Annual grass yield of San Dimas lysimeters

Lysimeter type	No.	Average yield (oven dry) 1940-41		1941-42	
		lb/sq.ft.	lb/acre	lb/sq.ft.	lb/acre
Unconfined	5	.088	3800	.026	1130
Large	25	.069	3000	.026	1130
Medium	26	.029	1260	.009	392
Small	68	.013	566	.009	392

Soil moisture samples taken in the large lysimeters during their seepage period in 1943 revealed that only within the top foot was the soil significantly drier than that at corresponding depths in the medium and small lysimeters. It may be that the differences in plant growth depend upon these observed top-soil differences. Soil sampling has not provided a basis upon which to judge the significance of yield differences between large and unconfined lysimeters. However, a comparison of the soil water content curves of the large and unconfined lysimeters (figs. 9 and 12) during the late spring of 1941 shows a far greater rate of moisture loss from the latter. This probably implies better growing conditions in the unconfined lysimeters, since the average water content of the two lysimeters was essentially the same. The almost equal rates of water loss from these two lysimeters noted during the corresponding period of the next year, coupled with the generally lower moistures which prevailed that year, may explain the equality of yield in the 1942 harvest.

Thus it is shown that, at least under conditions of complete annual recharge of soil moisture, the yield of annual grass diminishes progressively in the sequence: unconfined, large, medium, and small lysimeters (table 4). Under these conditions none of the lysimeter groups can be said to be producing comparable data and all three groups of enclosed lysimeters produce lower yields than do the most naturally exposed soil blocks, the unconfined lysimeters.

CONCLUSIONS

1. Under conditions of purely evaporative soil moisture loss or under a light cover of annual grass there is a close linear relation between the water content of the small and medium lysimeters. Over the period of study one set of constants for bare and one for grass-covered lysimeters has satisfied this relation. However, the same constants do not relate the two lysimeter groups under different treatments, showing that the method of handling the lysimeters influences the relation existing between them. It is suggested that the consistent relation found between small and medium lysimeters is the result of two causes: the complete moisture recharge of both each year, and the failure of evaporation and transpiration to reduce these soils to their wilting points.

If chaparral or other perennial vegetation were growing in these lysimeters, it is anticipated that the available water would be exhausted more rapidly in the small than in the medium lysimeters. Under these conditions it may be that the equation relating the two would be less simple and less significant.

2. Although a simple relation appears to exist between the water contents of the bare large and medium lysimeters during the dry season, the same relation does not hold for successive years. Nor does the summer relation hold during the rainy season. The relation between grass-covered lysimeters is only very general at any time. The inconsistencies brought out above show that the medium lysimeters cannot be considered to be models of the large ones and that in this case, as well as in that of the medium and small lysimeters, the treatment of the lysimeters has a considerable influence on the relation existing between them.

3. The unconfined lysimeters show no consistent relation to any of the other lysimeter types so far as the water regime is concerned. In grass yield, however, they are closely approximated by the large lysimeters. The unconfined lysimeters are fundamentally different from the others in that seepage from them is unobstructed while a soil/air interface is present in the other lysimeters. It appears probable that this difference in seepage condition has led to significantly different moisture distributions and growing conditions between the unconfined and other lysimeter groups.

IMPROVEMENTS IN LYSIMETER DESIGN

It is recognized that the unconfined lysimeters present conditions more closely approaching those in field soils than do any of the other lysimeters. The fact that the water losses from the other lysimeters do not agree with these implies short-comings in the design of the small, medium and large lysimeters. These short-comings are thought to exist in the form of: 1. the soil-over-air seepage interface; 2. too shallow a soil layer in medium and small lysimeters; and, 3. restricted surface runoff in medium and small lysimeters. As a result, too much water has entered the medium and small lysimeters, poorly aerated soil has led to subnormal plant growth, and inconsistent relations of evaporation and evapo-transpiration water losses have developed between the several types of lysimeters.

Improvements in the San Dimas installation involve providing for (a) complete surface drainage and extension of the soil depths in the medium and small lysimeters to the six-foot depth provided in the large ones and (b) modification of seepage conditions in all the enclosed soil blocks with a view toward minimizing the abnormal moisture conditions now prevailing. The method of accomplishing the last-mentioned improvement was made the subject of a recent study (3). This study demonstrated that excess water can be drained from a lysimeter by placing fine-pored fired-clay tubes in the lower part of the soil block and maintaining a moisture tension in the pores equal to that found in the soil at field capacity. The equipment required to perform this drainage function is not complicated in form or operation. It requires, however, special design and manufacture, and careful installation.

SUMMARY

Comparisons of the soil water cycle, annual evapo-transpiration values, and yield of annual grass, have been made between four types of lysimeters which are included in the San Dimas lysimeter installation. These lysimeters exhibit differences in depth, size, surface drainage, and seepage conditions. Some have been maintained bare and some have supported stands of Bromus mollis.

A unique relation was found to exist between the water content of cylindrical lysimeters 24 and 38 inches deep permitting the water content of one to be calculated at any time from that measured in the other. A somewhat less definite relation was found between these and the third type, a concrete box six feet in depth. Finally no unique relation was found between the enclosed, box-type lysimeter and six-foot deep pits filled with the same kind of soil. This latter "unconfined" lysimeter differed from the others in permitting seepage unobstructed by the soil/air seepage interface which caused the development of a saturated soil layer above the seepage plane of the other lysimeters.

Grass yields became progressively lower as soil depth decreased, not as a result of water lack, but more probably stemming from the poor aeration of the shallow soil blocks arising from the saturated soil present within their lower depths.

Since the "unconfined" lysimeters are the most nearly natural of the lysimeter types, improvements in lysimeter design should seek duplication of conditions within them. It is proposed that this can be accomplished by (1) increasing the depths of all soil blocks to six feet; (2) providing complete surface drainage; and (3) eliminating abnormal soil moisture condition by removal of the soil/air seepage interfaces.

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FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN

No 51 September 13, 1946

FOREST TREE SEED COLLECTION ZONES IN CALIFORNIA

By

H. A. Fowells, Silviculturist 1/

The forests of California are divided in this paper into forest tree seed collection zones. The zones are created for two reasons, the first of which is to insure that stock grown from any lot of seed is planted in an area with an environment comparable to that of the location in which the seed was collected. The great range of types and sites in the forests of California demands that the general principles of seed provenance be observed. The second reason for establishing seed collection zones is to simplify the keeping of records of seed lots. Records of individual seed lots have been maintained from seed collection to outplanting of the stock. These detailed records are of little value without adequate research concerning the performance of any seed lot in a given planting area.

1/ The author acknowledges the use of the vegetation type map of California prepared by the Forest Survey, California Forest and Range Experiment Station, and information furnished by Duncan Dunning of the same Station.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

The question of seed provenance is summarized by Baldwin[2] and need not be reviewed here in detail. The essence of research and experience in seed provenance is that, except for known superior strains or exotics, the best plantations result from seed collected from an area of comparable environment. This generality is recognized in the statement of the Seed Policy Committee of the United States Department of Agriculture[3] that it shall be the policy--

> 4. To use local seed from natural stands whenever available unless it has been demonstrated that seed from another specific source produces desirable plants for the locality and uses involved. Local seed means seed from an area subject to similar climatic influences and may usually be considered as that collected within 100 miles of the planting site and differing from it in elevation by less than 1000 feet.
>
> 5. When local seed is not available, to use seed from a region having as near as possible the same length of growing season, the same frequencies of summer drought, with other similar environment so far as possible, and the same latitude,

Strict adherence to this policy involves separate maintenance of individual seed lots from seed collection to outplanting. A simpler method of handling seed is here provided by recognizing seed collection zones based on forest type and site, which are assumed to be the integrated expression of environmental influences.

The forested portion of the vegetation type map of California prepared by the Forest Survey is used as the first subdivision of the state into seed collection zones. Within the broad vegetation classes, further subdivision is based on coniferous tree species composition, on site, and on latitude. A map of the 13 seed collection zones described in the following paragraphs is shown on plate 1. A larger, more detailed map was prepared for field use in 1945 and has been adopted by the Forest Service in California.

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[2] Baldwin, Henry I. Forest tree seed of the north temperate regions. 240 pp. Chronica Botanica Company, Waltham, Mass. 1942.

[3] McCall, M. A. Forest tree seed policy of the U. S. Department of Agriculture, Jour. Forestry 37: 820-821. 1939.

The timber stand of the east slope of the Sierra Nevada and of the Columbian plateau of northeastern California, consisting of ponderosa pine and Jeffrey pine with admixtures of Pacific white fir and California incense-cedar, is an obvious broad type. The site is predominantly quality III-125[4] and lower. A latitudinal division in the vicinity of Lake Tahoe creates two seed zones, which have been called the northern east-side Sierra and the southern east-side Sierra.

The west slope of the Sierra Nevada supports two broad timber types, the mixed conifer and the subalpine. On the lower and middle west slope of the Sierra Nevada and in the southern extension of the Cascade Range the timber stands are typically mixed conifer, containing ponderosa pine, sugar pine, Pacific white fir, and California incense-cedar, with Douglas-fir included in the northern part. In the vicinity of the Mokelumne River Douglas-fir ceases to be an important part of the stand. The Mokelumne River serves to divide the west slope into northern and southern zones.

A belt of high site quality, A-200 and I-175, exists along the lower slopes, ranging in elevation up to about 5,000 feet in the southern Sierra Nevada and up to about 4,000 feet in the northern Sierra Nevada. Above this belt site quality is usually II-150, III-125, and IV-100. The type division at the Mokelumne River and this additional division based on site delineates four zones which are designated: northern west-side Sierra, high site; northern west-side Sierra, low site; southern west-side Sierra, high site; and southern west-side Sierra, low site.

The upper slopes of the Sierra Nevada support a subalpine forest in which California red fir and Jeffrey pine are the only commercial species. A division of the subalpine type latitudinally in the vicinity of Lake Tahoe forms two zones, the northern subalpine, and the southern subalpine.

In southern California the timber stands are confined to rather small areas in discontinuous mountain ranges and are commercially unimportant. Separation on a map on the basis of type or site is impractical; accordingly, the whole area has been called the southern California zone.

The northern Coast Ranges of California support three distinguishable forest types. The redwoods extend along the coast in the fog belt, 10 to 30 miles in width. A break in the type occurs at Cape Mendocino. The redwood belt to the north is of relatively high site and contains as minor species Douglas-fir, western hemlock, Sitka spruce, grand fir, and Port Orford white cedar. South of Cape Mendocino the redwood stands are generally of lower site and contain principally Douglas-fir as a minor species. On this basis the region has been separated into the northern redwood and the southern redwood zones.

4/ For a discussion of site classifications, see "A site classification of the mixed-conifer selection forests of the Sierra Nevada," by Duncan Dunning. Research Note No. 28. California Forest and Range Experiment Station. 1942. (Processed.)

East of the fog belt and extending to lower elevations of the inner Coast Range and of the Klamath Mountains is an area predominantly Douglas-fir. The type, called the Douglas-fir zone, breaks out to the coast in the Cape Mendocino region, separating the redwood region as noted above.

Along the higher portions of the inner Coast Range and of the Klamath Mountains and extending east as far as the upper Sacramento River is a belt of mixed conifer timber of medium site which has been designated as the north coast pine zone. Some limited areas of subalpine type have not been excluded from this zone.

The zones thus established on the basis of forest type and site and on an arbitrary latitudinal division conform fairly well to the areal and altitudinal limitations of the policy quoted. In practice, seed collected in any zone would be labelled with the zone number, and stock grown from that seed would be planted anywhere within that zone. The planting of stock outside its zone, if necessary, should be confined to zones most similar. It is hoped that the zones as proposed will effect a practical application of the theoretically best seed policy and will fulfill the needs of nursery and planting administration.

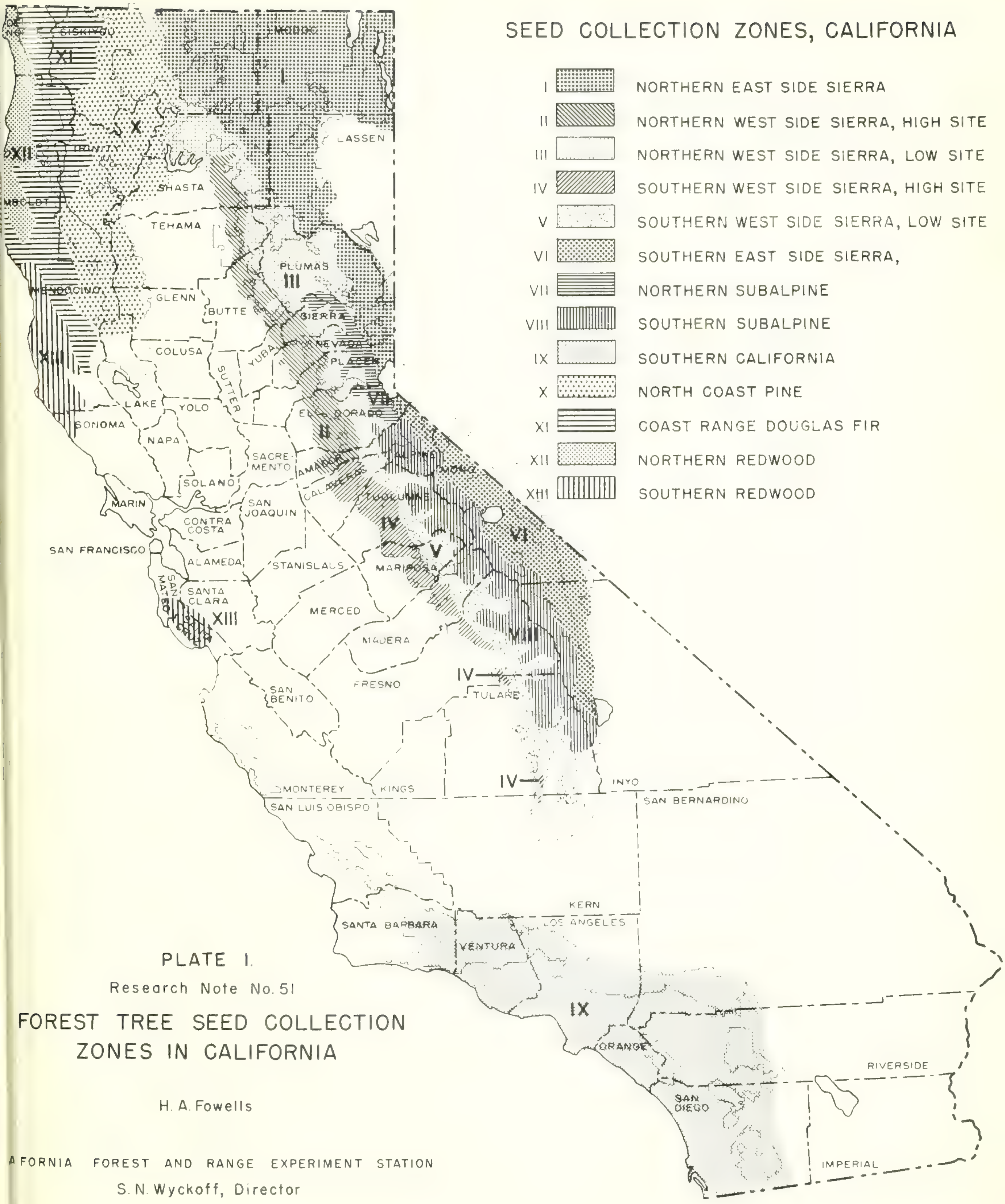

PLATE I.

Research Note No. 51

FOREST TREE SEED COLLECTION ZONES IN CALIFORNIA

H. A. Fowells

FORNIA FOREST AND RANGE EXPERIMENT STATION
S. N. Wyckoff, Director

ST SERVICE - U. S DEPARTMENT OF AGRICULTURE

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 52. October 15, 1945

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF [illegible]
[illegible]

ROOTS OF FOREST TREES

A selected list of references
compiled by

Duncan Dunning

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

ROOTS OF FOREST TREES

A selected list of references[1]
compiled by
Duncan Dunning[2]
California Forest and Range Experiment Station[3]

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[1] First issued 1928. Reissued 1946 and 1949.

[2] Grateful acknowledgement is made for assistance from Laura O. Baxter and Anne Avakian, former librarians, California Forest and Range Experiment Station; Sonia Wilderman Nielsen, librarian, Station WPA project; and Nellie G. Larson, U.S.D.A. Library, San Francisco Branch.

[3] Maintained by the Forest Service, U. S. Department of Agriculture at Berkeley, California, in cooperation with the University of California.

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FOREST RESEARCH NOTES

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 53 April, 1947

TREES IN THE EDDY ARBORETUM,[1]

Institute of Forest Genetics, Placerville, California

By

R. H. Weidman, Silviculturist

This list of trees in the Eddy Arboretum has been prepared to meet the requests of visitors and correspondents. It includes species, varieties, and hybrids, their scientific and common names, their native ranges, and the number of specimens.

In addition to a small number of miscellaneous trees, the Eddy Arboretum contains what is probably the most complete collection of pines to be found anywhere. The arboretum and its contiguous test plantations provide a study area for pine-breeding research of the Institute of Forest Genetics. Some 10,000 planted trees occupy 40 acres. Arboretum trees, mostly 18 to 20 years old in 1947, are between 30 and 70 feet tall. The hybrids and progeny test trees are younger. There are 70 species, 22 varieties, and 26 hybrids of the genus *Pinus*. Since research is restricted to pines, there has been no systematic planting of other conifers.

Deep clay-loam soil and mild climate combine to permit growing the wide range of pine species. The arboretum, at 2,700 feet elevation, is well above the hot central valley of California, but below the colder zones of the Sierra Nevada. Precipitation is 42 inches, all of which falls from October to May. Maximum temperatures rarely exceed 100 deg. F. Winter minimums are usually near 20 deg. F., but 12 degrees was recorded in 1937 and 16 degrees in 1932. Light winter snowfall usually melts in less than a week; one unusual storm in 22 years deposited 36 inches of snow, another deposited 16 inches.

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[1] Named in honor of James G. Eddy, who founded the Institute of Forest Genetics in 1925.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Pines cultured in the Eddy Arboretum, 1947

Scientific and common name	Native range	Number of trees
Pinus:		
albicaulis Engelm. whitebark pine	W. North America	1
aristata Engelm. bristlecone pine	S. W. United States	1
arizonica Engelm. Arizona pine	Arizona	20
Armandi Franch. Armand pine	China	4
attenuata Lemm. knobcone pine	California	61
ayacahuite Ehren. Mexican white pine	Mexico	4
Balfouriana Grev. & Balf. foxtail pine	California	2
banksiana Lamb. jack pine	E. North America	16
bungeana Zucc. lacebark pine	China	6
canariensis C. Smith Canary Island pine	Canary Islands	29
caribaea Morelet slash pine	Gulf of Mexico Region	92
cembra L. Swiss stone pine	Cen. Europe to N. Asia	2/ 9
cembroides Zucc. Mexican pinyon	Mexico	7
clausa (Engelm.) Vasey sand pine	S. E. United States	4
contorta Dougl. shore pine	W. North America	4
contorta var. *latifolia* Engelm. lodgepole pine	W. North America	52
contorta var. *Bolanderi* Vasey Bolander pine	W. North America	4
Coulteri D. Don Coulter pine	California	84
densiflora Sieb. & Zucc. Japanese red pine	Japan	31
durangensis Martinez Durango pine	Mexico	2
echinata Mill. shortleaf pine	S. E. United States	181
edulis Engelm. pinyon	S. W. United States	5

2/ These trees are in propagation in gallon cans.

Pines cultured in the Eddy Arboretum, 1947—*continued*

Scientific and common name	Native range	Number of trees
excelsa Wall. Himalayan pine	India	6
flexilis James limber pine	W. North America	7
Gerardiana Wall. Gerard pine	India	4
glabra Walt. spruce pine	S. E. United States	13
Greggii Engelm. Gregg pine	Mexico	8
halepensis Mill. Aleppo pine	Mediterranean Region	26
halepensis var. *brutia* Elw. & Henry erect cone Aleppo pine	Mediterranean Region	5
insularis Endl. Luzon pine	Burma to Philippines	1
Jeffreyi Grev. and Balf. Jeffrey pine	California	373
koraiensis Sieb. and Zucc. Korean pine	N. E. Asia	1
Lambertiana Dougl. sugar pine	California	184
latifolia Sarg. Apache pine	Arizona and N. Mexico	15
leiophylla Schl. and Cham. smoothleaf pine	Mexico	36
leucodermis Antoine graybark pine	Balkan Mts.	8
longifolia Roxburgh chir pine	India	27
luchuensis Mayr Luchu pine	Ryukyu Islands	3/ 10
Lumholtzii Rob. and Fern. Lumholtz pine	Mexico	1
Massoniana Lamb. Masson pine	China	9
monophylla Torr. & Frem. singleleaf pinyon	S. W. United States	3
montana Mill Swiss mountain pine	Central Europe	15
montana var. *Mughus* Willk. Mugho pine	Central Europe	12
montana var. *pumilio* Willk. shrubby Swiss pine	Central Europe	2
montana var. *uncinata* Willk. tree Swiss pine	Central Europe	10
montana var. *gallica* French mountain pine	Central Europe	3

3/ Identity of these trees is in doubt. Fifteen Luchu pines from seed collected on Okinawa Island in 1945 are now in propagation in gallon cans.

Pines cultured in the Eddy Arboretum, 1947—*continued*

Scientific and common name	Native range	Number of trees
montezumae Lamb. Montezuma pine	Mexico	40
montezumae var. *hartwegii* Engelm. Montezuma pine	Mexico	18
Montezumae var. *rudis* Shaw Montezuma pine	Mexico	2
monticola Dougl. western white pine	W. North America	74
muricata D. Don bishop pine	California	23
Nelsonii Shaw Nelson pine	Mexico	4/ 2
nigra var. *austriaca* Asch. & Graeb. Austrian pine	Mediterranean Region	20
nigra var. *calabrica* Schneid. Corsican pine	Mediterranean Region	29
nigra var. *cebennensis* Rehder Cevennes pine	Mediterranean Region	4
nigra var. *mauretanica* Mair & Peyer Algerian pine	Mediterranean Region	6
nigra var. *pallasiana* Asch. & Graeb. Crimean pine	Mediterranean Region	4
oocarpa Schiede eggcone pine	Mexico	13
palustris Mill. longleaf pine	S. E. United States	79
patula Schl. and Cham. Mexican weeping pine	Mexico	26
puece Griseb. Macedonian pine	Balkan Mts.	2
pinaster Ait. maritime pine	Mediterranean Region	20
pinaster var. *gigantea* maritime pine	Mediterranean Region	7
pinaster var. *hamiltonii* Gord. maritime pine	Mediterranean Region	4
pinceana Gord. Pinceana pine	Mexico	1
pinea L. Italian stone pine	Mediterranean Region	13
ponderosa Laws. 5/ ponderosa pine	W. North America	980
ponderosa var. *scopulorum* Engelm. Rocky Mountain ponderosa pine	Rocky Mountains	238
pseudostrobus Lindl. Nicaragua pine	Mexico to Nicaragua	7
pungens Lamb. Table Mountain pine	E. United States	18
quadrifolia Parl. Parry pinyon	California	7

4/ These trees are in propagation in gallon cans.

5/ The ponderosa trees include representatives from more than 50 sources from British Columbia to Mexico and from South Dakota to the Pacific Coast.

Pines cultured in the Eddy Arboretum, 1947—*continued*

Scientific and common name	Native range	Number o trees
radiata D. Don Monterey pine	California	254
radiata var. *binata* Lemm. Monterey pine	California	2
remorata Mason Santa Cruz pine	California	15
resinosa Ait. red pine	E. North America	17
rigida Mill. pitch pine	E. North America	66
rigida var. *serotina* (Michx.) Loud. pond pine	S. E. United States	12
Sabiniana Dougl. Digger pine	California	17
strobus L. eastern white pine	E. North America	52
sylvestris L. Scotch pine	North Europe and Asia	61
sylvestris var. *argentea* Steven silver Scotch pine	Caucasus Mountains	4
sylvestris var. *lapponica* Fries Lapland pine	Scandinavia	3
sylvestris var. *rigensis* Loud. Riga pine	Baltic Region	10
sylvestris var. *scotica* Beiss. Highlands pine	Scotland	6/ 22
tabulaeformis Carr. (*sinensis* Mayr) Chinese pine	China	26
taeda L. loblolly pine	S. E. United States	144
taewanensis Hayata Formosa pine	Formosa	8
teocote Schl. and Cham. Aztec pine	Mexico	1
Thunbergii Parl. Japanese black pine	Japan	10
Torreyana Parry Torrey pine	California	24
virginiana Mill. Virginia pine	S. E. United States	3
washoensis Mason & Stockwell Washoe pine	Nevada	9
yunnanensis Franch. Yunnan pine	China	7

6/ These trees are in propagation in gallon cans.

Hybrids cultured in the Eddy Arboretum, 1947[7]

Scientific name	Age of trees	Number of trees
	Years	
Pinus:		
x attenuradiata Stockwell and Righter (*attenuata x radiata*)	18	28
attenuata x (attenuata x radiata)	10	30
(attenuata x radiata) x (attenuata x radiata)	6–14	28
(attenuata x radiata) x attenuata	10	2
(attenuata x radiata) x radiata	10	2
arizonica x ponderosa	3	15
caribaea x taeda	10	3
contorta var. *latifolia x banksiana*	6	15
echinata x caribaea	14	7
echinata x rigida	12	22
echinata x taeda	5–8	80
Jeffreyi x Coulteri (natural hybrid)	5	55
Jeffreyi x (Jeffreyi x Coulteri)	5	105
Jeffreyi x ponderosa	14	8
monticola x excelsa	3–4	18
monticola x strobus	4–6	71
palustris x caribaea	12	18
ponderosa x Jeffreyi	14	1
ponderosa x latifolia	2–14	32
ponderosa x ponderosa var. *scopulorum*	3–18	120
rigida x taeda	2–12	16
x Sondereggeri H. H. Chapman (natural hybrid *taeda x palustris*)	14–20	111
strobus x excelsa	5	10
taeda x caribaea	12	8
taeda x palustris	13	2
washoensis x ponderosa	4	40

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[7] These are all outplanted trees. The largest 18-year-old *attenuradiata* trees are 60 feet tall.

Conifers and taxads other than pines in the Eddy Arboretum, 1947

Scientific and common name	Native range
Abies concolor (Gord. & Glend.) Hoopes white fir	Western North America
Abies grandis (Dougl.) Lindl. grand fir	Western North America
Abies magnifica A. Murr. red fir	California and Oregon
Abies religiosa Schl. & Cham. sacred fir	Mexico and Guatemala
Abies bracteata (D. Don) Nutt. bristlecone fir	California
Cedrus deodara Loud. deodar cedar	Himalaya Mountains
Callitris cupressiformis[8] Ventenat cypress pine	Australia
Cephalotaxus drupacea[8] Sieb. & Zucc. Japanese plum yew	Japan
Chamaecyparis Lawsoniana (A. Murr.) Parl. Port Orford cedar	S. W. Oregon to N. W. Californi
Cryptomeria japonica D. Don cryptomeria	Japan
Cunninghamia lanceolata Hook. Chinese fir	China
X Cupressocyparis Leylandii Dallim. and Jacks. Leyland cypress (*Chamaecyparis nootkatensis x Cupressus macrocarpa*)	
Cupressus arizonica var. *bonita* Lemm. Arizona cypress	Arizona
Cupressus funebris[8] Endl. mourning cypress	China
Cupressus Goveniana Gord. Gowen cypress	California
Cupressus guadalupensis S. Watson Guadalupe cypress	Mexico
Cupressus lusitanica Mill. Mexican cypress	Mexico and Guatemala
Cupressus macnabiana A. Murr. McNab cypress	Oregon and California
Cupressus nevadensis Abrams. Piute cypress	California
Cupressus sargentii Jeps. Sargent cypress	California
Cupressus sempervirens L. Italian cypress	Mediterranean Region
Ginkgo biloba Kaempfer Ginkgo	China
Juniperus cedrus Webb & Barth. Canary Island juniper	Canary Islands
Juniperus chinensis var. *japonica* Lav. Japanese juniper	Japan
Juniperus chinensis var. *pfitzeriana* Spaeth Pfitzer juniper	Horticultural variety
Juniperus horizontalis Moench. creeping juniper	Northern North America
Juniperus occidentalis Hook. western juniper	California to British Columbia
Juniperus sabina L. savin juniper	Europe
Juniperus scopulorum Sarg. Rocky Mountain juniper	Rocky Mountains

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[8] These trees are in propagation in gallon cans.

Conifers and taxads other than pines, 1947--*continued*

Scientific and common name	Native range
Juniperus virginiana L. eastern red cedar	Eastern North America
Larix europaea De Candolle (*L. decidua* Mill.) European larch	Europe and Siberia
Larix leptolepis Sieb. and Zucc. (*L. Kaempferi* Sarg.) Japanese larch	Japan
Libocedrus decurrens Torr. incense cedar	California and Oregon
Picea canadensis (Mill.) B.S.P. (*P. glauca* Voss) white spruce	Northern North America
Picea Engelmanni Parry Engelmann spruce	Western North America
Picea excelsa Link. (*p. abies* Karst.) Norway spruce	Northern Europe
Picea likiangensis Pritzel Likiang spruce	Western China
Picea mariana (Mill.) B.S.P. black spruce	Northern North America
Picea pungens Engelm. blue spruce	Colorado to Mexico
Picea purpurea Mast. (erroneously labeled *Picea Delavayi*) purple cone spruce	Western China
Picea sitchensis Carr. Sitka spruce	Northern California to Alaska
Podocarpus andina[9/] Poepp. podocarp	Chile
Podocarpus macrophylla[9/] D. Don podocarp	Japan
Pseudolarix amabilis[9/] Rehder golden larch	China
Pseudotsuga macrocarpa (Vasey) Mayr. bigcone spruce	Southern California
Pseudotsuga taxifolia (Poir.) Britton Douglas fir	British Columbia to Mexico
Pseudotsuga taxifolia var. *glauca* (Mayr) Sudw. Rocky Mountain Douglas fir	Rocky Mountains
Sequoia gigantea Decaisne giant Sequoia	California
Sequoia sempervirens Endl. redwood	California
Taxus brevifolia Nutt. Pacific yew	Western North America
Taxus baccata var. *fastigiata* Loud. Irish yew	Europe
Thuja occidentalis L. American arborvitae	Eastern North America
Thuja orientalis L. oriental arborvitae	Northeast China and Korea
Thuja plicata D. Don giant arborvitae	California to Alaska
Torreya californica Torr. California Torreya	California
Tsuga heterophylla (Raf.) Sarg. western hemlock	California to Alaska
Sciadopitys verticillata Sieb. and Zucc. umbrella pine	Japan

[9/] These trees are in propagation in gallon cans.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 55 October 1, 1947

PRODUCTION OF LUMBER AND OTHER SAWED PRODUCTS IN CALIFORNIA AND NEVADA, 1946 [1]

(Preliminary data, subject to revision)

By Richard H. May and Alexander Simontacchi [2]

Lumber production in California in 1946 broke all previous records with a total cut of slightly over 2,681,500 M feet b.m. (including a small amount from Nevada). This is all the more remarkable in view of the fact that a strike closed or curtailed production in the major Redwood Region mills during most of the year. Thus the Pine Region mills more than made up the volume of production lost by the redwood strike. The cut for 1946 is an 18.6 percent increase over that for 1945 and an 8.7 percent increase over that for 1944 -- the previous high year.

Tables 1 to 5, inclusive, present the details of lumber production by species, mill size class, and county. A new feature in this year's Research Note is a map of California showing the approximate location of mills contributing to the record cut of 1946.

Highlights of 1946 Lumber Production

Pine Region production increased 35.4 percent over 1945, or from 1,616,289 M bd. ft. to 2,189,208 M bd. ft. That of the Redwood Region dropped 23.6 percent below 1945, or from 644,503 M bd. ft. to 493,203 M bd. ft.

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[1] Preliminary statistics of lumber production in California and Nevada were collected in cooperation with the Bureau of the Census of the U. S. Department of Commerce. These data should be essentially correct, since they are based on preliminary tabulations of complete returns. Final statistics will, however, be issued by the Bureau of the Census in the usual manner.

[2] Foresters, Division of Forest Economics, California Forest and Range Experiment Station and Special Agents, Bureau of the Census. Blanche M. Fadie and Evelyn Huzieff, on the clerical staff of the California Forest and Range Experiment Station and Special Agents, Bureau of the Census, assisted in the compilation.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

The number of active sawmills almost doubled as compared with 1945, the increase being 99 percent or from 457 to 909. Active sawmills in the Pine Region increased by 87 percent over 1945 (from 341 to 646), while those in the Redwood Region increased by 127 percent (from 116 to 243). Active shingle mills increased 625 percent, or from 12 to 87. Total active mills of all types increased from 469 to 996, while total idle mills decreased from 123 to 55.

Figure 1 shows graphically the changes in lumber production and in number of active sawmills that occurred in the Pine and Redwood Regions from 1945 to 1946.

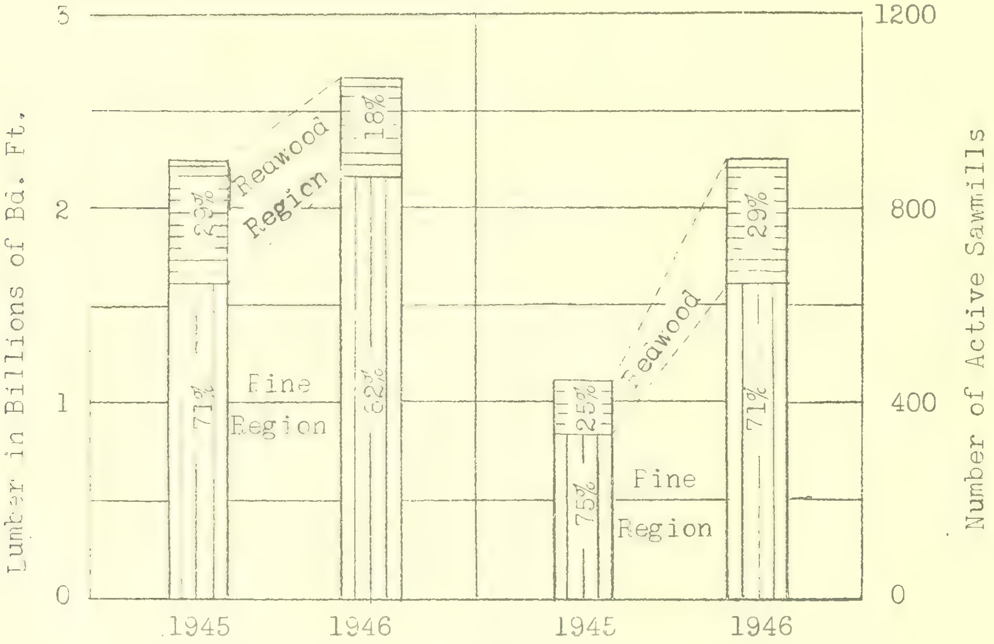

Figure 1. Lumber production and active sawmills in Pine and Redwood Regions, 1945 and 1946

The cut of all species except redwood, Port Orford cedar and the oaks increased. However, in the Pine Region the cut of firs advanced in proportion of total cut at the expense of the pine cut by about 3½ percent, or from 28.5 to 32.2 percent of the regional cut. In the Redwood Region, "whitewoods" (Douglas fir and other species) advanced at the expense of redwood by almost 20 percent, or from 31.1 to 50.8 percent of the regional cut.

The medium-sized and, to lesser extent, the small mills increased in proportion of total cut at the expense of the large mills. For the State[3] as a whole, Class 3 and 4 mills produced 33 percent of the total cut in 1946, while their proportion in 1945 was 23½ percent. This is most noticeable in the Redwood Region where Class 3 and 4 mills produced 61½ percent of regional cut in 1946 as compared with 23 percent in 1945.

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[3] State as here used refers to California primarily, for the Nevada cut, while included, is so small as to be negligible.

Owing to the redwood strike, no mills in the Redwood Region cut into Class 8 in 1946; while Pine Region mills in Class 8 cut less than in 1945, both as to total cut and proportion of cut. On the other hand, Class 7 mills in the Pine Region cut considerably more -- both in amount and percentage of total -- in 1946 than in 1945.

The three Class 8 mills in the Pine Region had a greater aggregate cut than any one county in California.

Siskiyou County regained the lead in production from Humboldt County, which dropped into second place because of the redwood strike. The 10 leading counties listed below accounted for 87½ percent of the State cut, though they contained only 55 percent of the active mills (499 of the total of 909).

County	1946 cut (M bd. ft.)
Siskiyou	293,113
Humboldt	271,545
Plumas	223,729
Lassen	221,485
Eldorado	211,979
Shasta	209,562
Mendocino	144,674
Butte	126,868
Calaveras	111,203
Tuolumne	102,619
	1,916,777

Mills with band headsaws, only 9 percent of the State total as to number, accounted for 60 percent of production by volume, with circular-headsaw mills cutting the remainder.

Lumber stocks had increased 18 percent by the end of 1946 as compared with the end of 1945, indicating the promise of a greater supply of better lumber in the future. This increase was primarily accounted for by Pine Region mills.

Cut of ties, lath and shingles increased over 1945, the lath cut by as much as 116 percent.

The State of Nevada cut only 93 M bd. ft. at three new small mills. The five older mills in that State were idle.

Careful estimates of production through the end of May 1947 indicate that the 1947 cut will exceed that of 1946, possibly by as much as 30 percent, thus forecasting a cut well over three billion bd. ft. for the State.

Table 1. Production of lumber, by species, and of other sawed products California and Nevada [1] - 1945 and 1946

Species	Lumber production 1945		Lumber production 1946		Change 1946 from 1945
	M bd. ft.	Percent	M bd. ft.	Percent	Percent
Ponderosa pine [2]	914,880	40.5	1,137,026	42.3	+ 24
Douglas fir	372,885	16.5	507,227	18.9	+ 36
White fir [3]	285,638	12.7	386,863	14.5	+ 35
Sugar pine	194,532	8.6	290,758	10.8	+ 49
Redwood [4]	443,806	19.6	243,310	9.1	- 45
Incense cedar	45,655	2.0	62,578	2.3	+ 37
California red fir [5]	--	-	40,044	1.5	--
Sitka spruce	2,328	0.1	7,203	0.3	+ 209
Other pines [6]	10	0.0	4,488	0.2	+ 44780
Port Orford cedar	665	0.0	510	0.0	23
Western hemlock [5]	-		75	0.0	
Total softwoods	2,260,399	100.0	2,680,082	99.9	+ 19
Alder	67	0.0	956	0.1	+ 1325
Oak [7]	274	0.0	273	0.0	0.5
Other hardwoods [8]	52	0.0	200	0.0	+ 285
Total hardwoods	393	0.0	1,429	0.1	+ 264
GRAND TOTAL	2,260,792	100.0	2,681,511	100.0	+ 19
Active sawmills reporting	457		909		+ 99
Stocks of lumber December 31 (M bd. ft.)	463,624		545,425		+ 18
Sawed ties, M bd. ft. [9]	27,503		33,094		+ 20
Active shingle and lath mills	12		87		+ 625
Lath and carstrips (thousands)	5,651		12,213		+ 116
Shingles and sawn shakes (squares)	89,328		127,997		+ 43

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[1] Combined to avoid disclosing output of individual establishments in Nevada in 1945.

[2] Includes Jeffrey pine, both years.

[3] Includes some California red fir and western hemlock in 1945.

[4] Includes bigtree, both years.

[5] Not reported separately in 1945 (included with white fir).

[6] Lodgepole pine in 1945. Monterey, Coulter, digger, lodgepole, western white pines in 1946.

[7] Valley white and California black oaks and tanoak in 1945. Valley white, California black, blue and live oaks and tanoak in 1946.

[8] Cottonwood, ash, laurel, and maple in 1945. Cottonwood and laurel in 1946.

[9] Also included under quantity of lumber sawed.

Table 2. Production of lumber by species and mill class, and lumber stocks

Pine Region [1] - California and Nevada, 1946

(Preliminary data subject to revision)

Production size class	Number of sawmills		Lumber sawed by species (M bd. ft.)											Lumber stocks (M bd. ft.)	
												All species			
	Active	Idle	Ponderosa pine [2]	Sugar pine	Douglas fir	White fir	Incense cedar	California red fir	Other pines [3]	Big-tree	Hardwoods [4]	Quantity	Percent	Dec. 31, 1945	Dec. 31, 1946
8 (50 MM and over)	3	0	199,368	33,805	17,759	41,662	2,470	4,275	0	0	0	299,339	13.7	48,729	40,280
7 (25 MM to 50 MM)	18	0	271,093	134,759	57,296	152,514	12,432	4,366	0	0	0	632,460	28.9	185,932	226,413
6 (15 MM to 25 MM)	16	2	153,785	34,782	37,024	58,498	7,179	15,813	0	0	0	307,081	14.0	71,708	112,960
5 (10 MM to 15 MM)	23	0	117,078	34,566	45,661	57,693	6,257	10,769	0	0	0	272,024	12.4	37,703	39,576
4 (5 MM to 10 MM)	38	0	142,665	22,097	42,801	24,489	21,441	1,463	0	0	0	254,956	11.6	26,969	26,011
3 (1 MM to 5 MM)	144	2	178,050	25,307	71,303	35,990	10,819	2,040	18	106	85	323,718	14.8	11,501	8,922
2 (500 M to 1 MM)	73	0	31,696	2,911	7,382	6,946	1,083	1,253	280	95	2	51,640	2.4	250	1,927
1 (50 M to 500 M)	225	15	33,209	2,409	5,190	2,940	848	48	381	271	173	45,469	2.1	305	1,446
0 Calif.	103	15	1,783	122	246	146	49	17	9	3	45	2,420	0.1	75	181
(Under 50 M) Nevada	3	3 [5]	87	0	0	6	0	0	0	0	0	93	0.0 [6]	0	0
All Classes: AMOUNT	646	37	1,128,814	290,758	284,662	380,884	62,578	40,044	688	475	305	2,189,208		383,172	457,716
PERCENT			51.6	13.3	13.0	17.4	2.9	1.8	0.0 [6]	0.0 [6]	0.0 [6]		100.0		

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[1] Includes all counties of California not listed in Redwood Region (Table 3, footnote 1). See also map on last page.

[2] Includes Jeffrey pine in eastern and southern counties of California, and in Nevada.

[3] Lodgepole pine 141M, western white pine 6M, Coulter pine 501M, digger pine 40M.

[4] Valley white oak 225M, alder 32M, blue oak 23M, California black oak 23M, coast live oak 2M, and cottonwood 2M.

[5] In addition to Nevada mills listed under Class 0, one idle Class 3 mill and one idle Class 1 mill were located in Nevada.

[6] Negligible; less than 0.05 percent.

Table 3. Production of lumber, by species and mill class, and lumber stocks

California Redwood Region 1/ - 1946

(Preliminary data, subject to revision)

Production size class	Number of sawmills		Lumber sawed by species (M bd. ft.)												Lumber stocks (M bd. ft.)	
													All species			
	Active	Idle	Redwood	Douglas fir	Ponderosa pine	Sitka spruce	White fir	Monterey pine	Port Orford cedar	Western hemlock	Alder	Other 2/ hardwoods	Quantity	Percent	Dec. 31, 1945	Dec. 31, 1946
8 3/ (50 MM and over)	0	0											0	0		
7 3/ (25 MM to 50 MM)	3	0	60,064	29,286	0	3,751	1,933	0	0	0	0	0	95,034	19.3	17,953	21,049
6 and 5 4/ (10 MM to 25 MM)	4	0	22,256	29,527	0	0	64	0	0	0	0	0	51,847	10.5	9,062	6,888
4 (5 MM to 10 MM)	17	1	55,574	66,081	580	0	1,800	0	468	0	0	0	124,503	25.3	16,309	19,028
3 (1 MM to 5 MM)	79	0	85,557	77,449	6,738	2,163	1,580	3,599	0	0	800	2	177,888	36.2	36,964	40,343
2 (500 M to 1 MM)	33	0	11,336	11,374	450	0	95	0	42	0	0	0	23,297	4.7	40	97
1 (50 M to 500 M)	93	3	7,564	8,582	444	1,281	507	194	0	75	124	198	18,969	3.8	123	241
0 (Under 50 M)	34	9	484	266	0	8	0	7	0	0	0	0	765	0.2	1	63
All Classes: AMOUNT	263	13	242,835	222,565	8,212	7,203	5,979	3,800	510	75	924	200	492,303 ~~493,203~~		80,452	87,709
All Classes: PERCENT			49.2	45.3	1.7	1.5	1.2	0.8	0.1	0.0 5/	0.2	0.0 5/		100.0		

1/ Redwood region includes counties of Del Norte, western Humboldt, western Mendocino, Sonoma, western Napa, Marin, San Mateo, Santa Clara, Santa Cruz and Monterey. (See map on last page).

2/ Cottonwood 193M, California laurel 5M, tanoak 2M.

3/ Classes 8 and 7 have less than normal production this year due to the strike which closed the major redwood mills for 6 months, and kept them at only partial capacity for several months longer.

4/ Classes 5 and 6 combined to avoid disclosure of individual establishments.

5/ Negligible; less than 0.05 percent.

Table 4. Production of ties, lath and carstrips, shingles and sawed shakes California 1/ - 1946

Region and type of mill	Mills		Sawed crossties 2/	Lath and carstrips	Shingles	Sawed shakes 3/
	Active	Idle				
	No.	No.	M ft. b. m.	M pcs.	Squares	Squares
PINE						
Sawmill 4/	--	--	27,086	9,090	100	0
Lath or shingle mill	42	2	0	1,828	25,489	0
Region total	--	--	27,086	10,918	25,589	0
REDWOOD						
Sawmill 4/	--	--	6,008	261	6,217	91
Lath, shingle or shake	45	3	0	1,034	82,766	13,334
Region total	-	--	6,008	1,295	88,983	13,425
STATE TOTAL	87	5	33,094	12,213	114,572	13,425

1/ None produced in Nevada.

2/ Ties, 9 ft. and less in length, which are also included in quantity of lumber sawed in Tables 1, 2, 3 and 5.

3/ Shakes sawed on one side split on other; also known as "Hollywood" shakes, "Monterey" shakes, or "shingle shakes."

4/ Lath, shingle, or shake machine in conjunction with sawmill.

Table 5. Production of lumber by counties and species

California and Nevada - 1946

(Preliminary data subject to revision)

State County	No. of active sawmills	Ponderosa pine 1/	Douglas fir	True firs 2/	Sugar pine	Redwood 3/	Cedar 4/	Sitka spruce	Other softwoods 5/	Hardwoods 6/	Total	Change from 1945
		Lumber production by species (M bd.ft.)										Percent
REDWOOD REGION												
CALIFORNIA												
Del Norte	15		14,206	10		36,692	114	2,616	75	10	53,723	+ 141
Humboldt (W)	93	20	137,806	5,392		110,755	396	4,587		222	259,178	- 35 9/
Marin - Napa (W) 7/	3	50	531			4,889					5,470	— 10/
Mendocino (W)	85	8,142	58,224	577		67,437				892	135,272	- 26 11/
Monterey	5					719			3,793		4,512	— 12/
San Mateo	6		708			3,664					4,372	+ 48
Santa Clara	3		370			695					1,065	+ 82
Santa Cruz	25		2,698			13,744			7		16,449	+ 61
Sonoma	28		5,022			4,240					12,262	+ 245
Region Total	263	8,212	222,565	5,979		242,835	510	7,203	3,875	1,124	492,303	- 24
PINE REGION												
CALIFORNIA												
Amador - Sacramento 7/	17	33,919	3,543	14,532	17,166		5,835				74,995	+ 55
Butte	44	39,993	20,671	37,270	26,339		2,595				126,868	+ 35
Calaveras	41	55,088	11,204	24,596	17,067		3,248				111,203	+ 18
Eldorado	65	114,161	19,979	36,293	29,612		11,926		8		211,979	+ 47
Fresno	21	16,465		11,171	9,808	80	140				37,664	+ 95
Glenn - Colusa	3	224	6	800	7						1,037	— 10/
Humboldt (E)	7	60	12,032		250		25				12,367	— 9/
Inyo - Alpine 7/	3	7,702		5,776					20		13,498	— 10/
Kern - San Luis Obispo 7/	5	1,130	100 8/	382	80		12			2	1,706	— 10/
Lake	9	6,335	4,617		26					225	11,203	+ 49
Lassen	11	155,881	3,085	48,585	11,505		2,429				221,485	- 10
Madera	20	13,746		4,756	3,311		178				21,991	+ 17
Mariposa	34	17,257		525	2,488		405				20,675	+ 140
Mendocino (E)	8	2,612	5,026	1,090	670		4				9,402	— 11/
Modoc	9	81,248		9,765			450				91,463	+ 56
Napa (E)	4	274	459								733	— 12/
Nevada	45	46,808	7,131	13,280	4,567		2,264			10	74,060	+ 278
Placer	26	22,547	11,005	5,446	1,102		618		1	1	40,720	+ 68
Plumas	28	63,404	44,320	66,413	35,849		13,643		100		223,729	+ 24
Riverside - Ventura 7/	7	913	200 8/	407	276		123				1,919	— 10/
San Bernardino	7	1,369		72	8		7		26		1,482	+ 108
San Diego	7	653		469	13		280		475	31	1,921	+ 668
Shasta	43	98,723	43,414	31,653	27,106		8,609		40	17	209,562	+ 50
Sierra	11	28,441	6,947	12,604	4,681		238		15		52,926	+ 19
Siskiyou	40	178,703	37,146	33,603	42,201		1,460				293,113	+ 9
Tehama	14	18,427	5,095	5,946	5,628		1,542			12	36,650	+ 148
Trinity	29	13,270	20,298	96	2,164		38				35,866	+ 101
Tulare	20	15,296		22,236	7,130	395	1,814		3	4	46,878	+ 99
Tuolumne	34	53,733	1,511	14,507	29,741		3,124			3	102,619	+ 73
Yuba	31	40,345	26,873	18,649	11,963		1,571				99,401	+ 72
NEVADA												
Douglas - Clark 7/	3	87		6							93	- 97
Region Total	646	1,128,814	284,662	420,928	290,758	475	62,578		688	305	2,189,208	+ 66
GRAND TOTAL	909	1,137,026	507,227	426,907	290,758	243,310	63,088	7,203	4,563	1,429	2,681,511	+ 19

1/ Includes Jeffrey pine, in some pine region counties.

2/ In Redwood Region: Lowland white fir (Abies grandis). In Pine Region: White fir (Abies concolor) and California red fir (Abies magnifica).

3/ In Redwood Region: Coast redwood. In Pine Region: Bigtree.

4/ In Redwood Region: Port Orford cedar. In Pine Region: Incense cedar.

5/ In Redwood Region: Western hemlock 75M, and Monterey pine 3800M. In Pine Region: Lodgepole pine 141M, western white pine 6M, digger pine 40M and Coulter pine 501M.

6/ In Redwood Region: Alder 924M, cottonwood 193M, laurel 5M and tanoak 2M. In Pine Region: Valley white oak 225M, alder 32M, blue oak 23M, California black oak 21M and coast live oak and cottonwood 2M each.

7/ Combined to avoid disclosing individual operations.

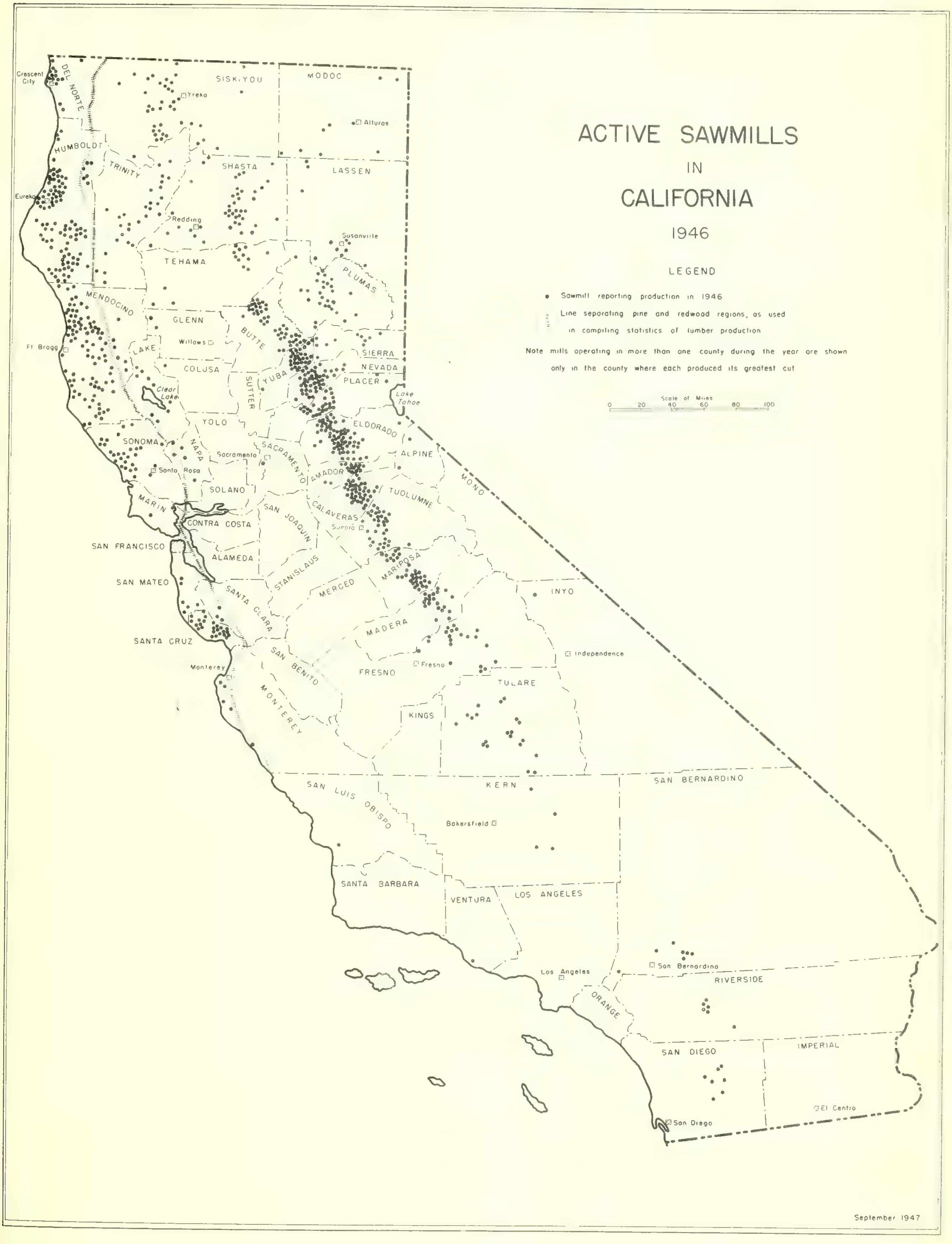
8/ "Dunnage", or old timbers.

9/ Humboldt W and Humboldt E combined for percentage computation.

10/ In different combination in 1945.

11/ Mendocino W and Mendocino E combined for percentage computation.

12/ No production in 1945.



ACTIVE SAWMILLS IN CALIFORNIA 1946

LEGEND

- ● Sawmill reporting production in 1946
- Line separating pine and redwood regions, as used in compiling statistics of lumber production

Note mills operating in more than one county during the year are shown only in the county where each produced its greatest cut

September 1947

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 57 April 1948

PINUS: POLLINATION BAG CONSTRUCTION

By A. R. Liddicoet

In plant breeding work different species usually require at least minor differences in treatment. It is not surprising, therefore, to learn that specific techniques are used in the breeding of pine trees. Methods and specialized equipment have been developed by the Institute of Forest Genetics over a period of twenty years, during which time many variations of numerous methods have been tried with more or less success. In an effort to help others who are interested in the breeding of pines, techniques that have proved successful are being published by the California Forest and Range Experiment Station. This note describes the construction of the pollination bag used by the Institute.[1]

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[1] Other recent publications include:

Pinus: Methods of controlling pollination in the Sierra Nevada, by W. C. Cumming and F. I. Righter. Manuscript in process of publication by U. S. Department of Agriculture.

Trees in the Eddy Arboretum, by R. H. Weidman. Research Note No. 53, California Forest and Range Experiment Station. Berkeley. April 1947.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Agriculture--Berkeley

Purpose of the Bag

In controlled pollination of pines a pollination bag is used to cover the female flowers, or conelets, to protect them from undesired pollen. The bags must be constructed of material that will exclude all air-borne pollen, yet will be porous enough to allow moisture transpired by pine needles to be dissipated. The bag material must allow penetration of a hypodermic syringe needle to introduce the pollen and must permit the hole made by the needle to be readily closed. It is also desirable that the bag have a window for examining the conelets without removing the bag.

Material. - The materials used in making the Institute bag are as follows:

Untreated 10- or 12- ounce white canvas. Twenty-eight-inch width is preferred because this width places selvedge edges at the open end of the bag. Bags made of 10-ounce canvas are preferable. They are lighter, easier to use, and cause less damage to young shoots than the more durable 12-ounce material.

Liquid fabric cement (weatherproof) and thinner. (One gallon will seal 250 bags).

No. 1 binding staples ($\frac{1}{2}$-inch wide).

Cellulose acetate plastic windows, 4 x 5 inches, .01 inch thick.

Cement for cellulose acetate. (One quart will cement 225 windows).

Cutting and Cementing. - A cardboard template (fig. 1) is used as a pattern to mark out the bag, which is 8 inches wide and 14 inches long when completed.

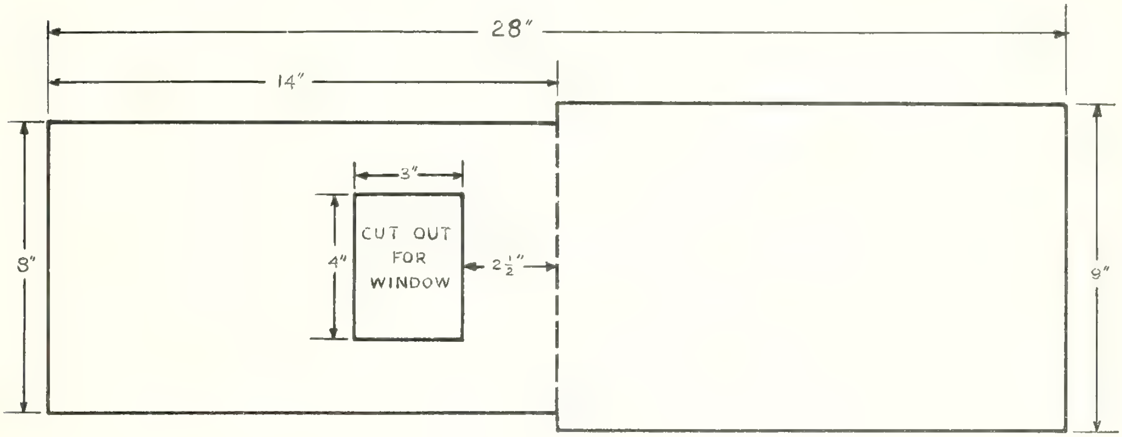

Figure 1. - Pattern for pollination bag template. (Not to scale.)

After the bag is cut by use of a single-edge razor blade or shears, the window half of the canvas is folded over, on the broken line of figure 1, leaving a half-inch margin beyond each edge of the 8-inch side. Liquid fabric cement is applied liberally to these margins, which are then folded over and sealed by running a finger along the lap. The newly glued bags are piled under a board weighted with about ten pounds. Such a weight is sufficient to press approximately 25 bags. After twenty-four hours the bags are inspected. If seams failed to adhere, they are re-cemented. A binding staple is placed in each corner with a No. 1 stapler to strengthen the corners.

Installing the Windows. - The windows are cut from standard 20- by 50-inch cellulose acetate sheets, each window being 4 by 5 inches so that it extends one-half inch on each side of the opening in the canvas. Cement is applied to the edge of the fabric with a half-inch brush. The window is placed in position, and sealed by pressure with the finger. The bag is again weighted as for cementing and left for twelve hours or more.

When the bag is completed, a piece of cotton batting is placed inside the bag (for padding around the branch where the bag is to be tied), the open end of the bag is sealed with gummed tape (fig. 2), and the bag is sterilized - as far as pollen is concerned - in an electric oven at 80° C for 24 hours.

This method of bag construction requires approximately 15 man-minutes to complete one bag. Under average treatment a bag will last from 10 to 15 years, except for the windows, which must be replaced in from 1 to 5 years. When replacing a window, if the defective one cannot be peeled from the canvas, a little acetone applied to the seams will help loosen the window. After each period of use the inside of the bag is cleaned with a small vacuum cleaner, and windows and seams are inspected for defects. If there are no defects, the bag is ready to have a piece of cotton placed inside and the open end sealed. When sterilized, the bag is again ready for use.

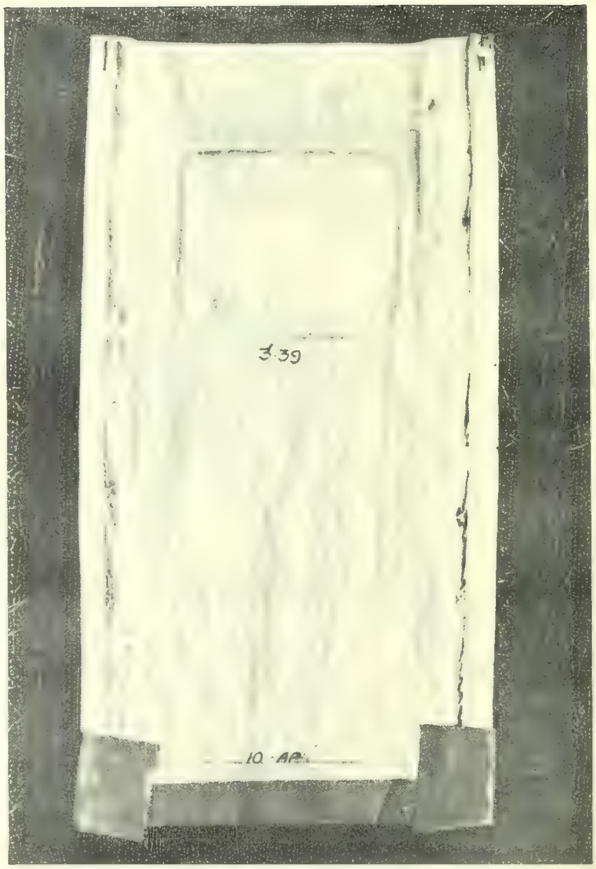

Figure 2 - Completed pollination bag sealed with gummed tape at open end.

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CALIFORNIA FOREST AND RANGE
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SOME ECONOMIC ASPECTS OF GROWING SUGAR PINE IN CALIFORNIA

By

Henry J. Vaux, Forest Economist

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Research, particularly in management techniques, will obviously have to be carried on for several years before definitive results can be obtained. Meanwhile, public programs concerned with the blister rust problem will continue in operation and administrative decisions governing both the scale of such programs and their application to specific areas will continue to be made. There is thus a pressing need for preliminary study of the blister rust-sugar pine management problem, even though results of such study are recognized as highly tentative.

Purpose and Limitations of this Report

To meet this need, available information on prospective sugar pine market requirements, stumpage values, and production costs has been brought together in this report. Primary attention has been directed to three specific questions:

1. About how much sugar pine will be needed by the time potential second growth crops reach maturity?

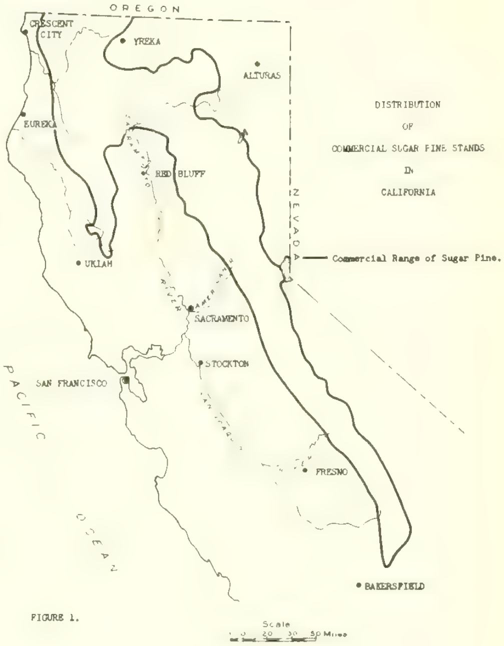
2. What is the long run outlook for sugar pine values and for value differentials between sugar pine and other species competing for sugar pine sites?

3. What elements of cost are likely to be most important in determining the spread between costs of growing sugar pine and costs of growing other species on the same site?

Such conclusions as are drawn in this report are tentative in character. Data are not currently available which will permit final decisions on some of the important questions which are involved. Other aspects are currently the subject of intensive research study, results of which may alter or modify views that now seem reasonable. But if these limitations are borne in mind, the results of the present study should prove helpful in formulating policies until such time as more thorough research is available.

Sugar Pine Forests in California

Economic problems of protecting and managing sugar pine stands must be considered in relation to the present condition of the sugar pine resource. Sugar pine ranges from central Oregon southward through the Coast and Cascade Ranges, the Sierra Nevada, and California cross ranges, into lower California. Its commercial range includes the west side of the Sierra Nevada, the inner Coast Range, the Siskiyou Mountains, and the Southern Cascade range. The species usually occurs in mixed stands. At lower elevations, primary associates are ponderosa pine, incense cedar, Douglas-fir, and oak. Higher up, white and red firs enter the mixture in increasing proportions, and other associates tend to disappear.



DISTRIBUTION OF COMMERCIAL SUGAR PINE STANDS IN CALIFORNIA

FIGURE 1.

Sugar Pine Types

For this report, two types of sugar pine forest have been recognized.

a. Sugar pine—fir type: an area in which sugar pine is the key species, forming 15 percent or more of the stand by volume, and in which the volume of firs (true fir or Douglas-fir) is 50 percent or more of total volume, or in which the volume in fir is two or more times the volume in ponderosa pine.

b. Sugar pine—ponderosa pine type: an area in which sugar pine is the key species, forming 15 percent or more of the stand by volume, and in which the volume of firs is less than 50 percent of total volume and less than twice the volume of ponderosa pine.

Sugar pine—ponderosa pine type thus includes not only "pure pine" types, with sugar pine 15 percent or more of the volume, but also stands of sugar pine and ponderosa pine mixed with smaller amounts of Douglas-fir and true fir. Similarly sugar pine—fir type includes not only those areas where ponderosa pine is absent, but also many mixed stands where ponderosa pine is present in small quantities. As an extreme illustration, an area consisting of 15 percent sugar pine, 34 percent ponderosa pine, and 51 percent firs is classified as sugar pine—fir type under this definition.[1]

Area of Sugar Pine Land

The Office of Blister Rust Control has estimated the forest area in sugar pine types in California at 3.1 million acres. This constitutes 18 percent of all timber cropland in the State and 27 percent of the land in pine and mixed coniferous forest types. An additional 2.2 million acres has sugar pine timber on it, but in insufficient quantity to be classed as sugar pine type. About 30 percent of the total acreage is in the southern Sierras (South of the American River, fig. 1). An additional 45 percent is in the northern Sierras, and the remaining 25 percent is in the Coast Range and Siskiyou Mountains.

Complete ownership data have not been compiled. On the basis of Office of Blister Rust Control figures covering over half of the type, however, about 52 percent of the area is in private ownership. The remainder is held largely by the Federal government. Private ownership dominates in the Sierra region with almost 60 percent of the sugar pine land. In the Coast Range and Siskiyous, private owners hold only about 30 percent of the sugar pine area. Throughout the region, 88 percent of the private ownership is in large holdings.

As with ownership, comprehensive data on distribution of the sugar pine area by site quality is not available. Generalized estimates, however (table 1), show that of the total forest area in sugar pine types about one quarter is on high-quality sites (defined as site class I-175 or better). Almost all of this 810 thousand acres of highly productive sugar pine land is in the West Sierra Pine subregion, with only about 50 thousand acres of high-site sugar pine type in the Coast Range.

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[1] This two-fold classification was dictated by the character of the data available for use in this analysis. It does not conform to the type classifications now in general use throughout the region. In particular, it should be noted that the important mixed conifer type is not recognized in the classification used here. Mixed conifer stands running predominantly to fir are here grouped with sugar pine—fir type, and those in which pine predominates are grouped with sugar pine—ponderosa pine type.

Table 1.- Estimated areas of sugar pine type in California by site quality[1]

(Area in thousand acres)

Subregion and forest type	Site quality[2]			
	High	Medium	Low	All sites
East Sierra Pine:				
Sugar pine--ponderosa pine	0	45	160	205
Sugar pine—fir	0	25	20	45
Total	0	70	180	250
West Sierra Pine:				
Sugar pine—ponderosa pine	400	530	50	980
Sugar pine—fir	360	460	40	860
Total	760	990	90	1,840
Coast Range Pine and Douglas-fir	50	860	60	970
All Subregions	810	1,920	330	3,060
Percent of total sugar pine area	26	63	11	100

[1] Estimates based on type maps prepared by Office of Blister Rust Control and data on site quality classes, by forest types and subregions, prepared by the California Forest and Range Experiment Station.

[2] High site includes sites IA-200 and I-175; medium site includes sites II-150 and III-125; low sites include site IV-100 and V-75.

Volumes of Sugar Pine Timber

According to volume estimates compiled by the Experiment Station, the total stand of sugar pine in California in 1945 amounted to 21.1 billion board feet. Of this, 1.6 billion feet was in areas where such factors as topography, accessibility, and character of timber are judged unfavorable for economic operation, at least for a long time to come. About 0.8 billion board feet was in areas of such high recreational value that the usual forms of timber management would not apply and is therefore of doubtful availability from the standpoint of sugar pine supply. This leaves 17.4 billion feet of available sugar pine timber in California (table 2). Fifty-six percent of this volume is in public ownership, and practically all of the publicly-owned volume is on national forests.

Seventy-eight percent of the available volume is in old-growth stands. Most of the remainder is in young growth-old growth stands and consists principally of residual old growth trees. Sugar pine volumes in young-growth stands amounted to only about 250 million board feet, 1.3 percent of the total available supply. In comparison, almost 5 percent of current ponderosa pine volumes are in young-growth stands. The difference is probably indicative of the difficulties of obtaining sugar pine restocking under past management practices.

As in the case of sugar pine areas, volumes are heavily concentrated in the West Sierra Pine subregion. It contains 73 percent of the total volume. Seventeen percent is in the Coast Range Pine area, and 8 percent in the East Sierra Pine. Volumes in the Douglas-fir and Redwood subregions account for only 2 percent of the total.

Table 2.- Available sugar pine volumes in California by subregion, ownership, and age class of timber

(Volumes in million ft., log scale)

Subregion and age class	Ownership Private	 Public[1]	All
WEST SIERRA PINE:			
Old growth	3,803	5,685	9,488
Young growth-old growth	1,508	1,499	3,007
Young growth	76	146	222
All ages	5,387	7,330	12,717
EAST SIERRA PINE:			
Old growth	874	351	1,225
Young growth-old growth	51	61	112
Young growth	2	6	8
All ages	927	418	1,345
COAST RANGE PINE, DOUGLAS-FIR, & REDWOOD:			
Old growth	1,091	1,826	2,917
Young growth-old growth	229	145	374
Young growth	17	7	24
All ages	1,337	1,978	3,315
TOTAL CALIFORNIA:			
Old growth	5,768	7,862	13,630
Young growth-old growth	1,788	1,705	3,493
Young growth	95	160	255
All ages	7,651	9,727	17,378

[1] Over 98 percent of the publicly owned sugar pine is in National Forests.

Totals may not add because of rounding.

The Blister Rust Situation

No description of the sugar pine resource would be complete without some reference to the present and prospective effect of white pine blister rust. Once firmly established in an area, this disease quickly causes high mortality in young sugar pine stands. Mature trees suffer much less heavily, but after many years of exposure, these too may be killed. Thus, one of the major factors to be considered in evaluating the sugar pine resource is the extent to which present volumes may be reduced by blister rust damage.

White pine blister rust was discovered in California in 1936 about 14 miles south of the Oregon border. Since then it has spread as far south as San Mateo County on the west and Amador county on the east. The disease has increased in intensity in the northern part of the State to such a degree that the young sugar pines are either dead or dying in many places where control measures have not been adopted. Farther south, it has not yet reached epidemic proportions.

Large scale practical control work was begun in California in 1933 and has continued to the present. Ribes have been removed once from 795 thousand acres of sugar pine land, and additional work to maintain control on these areas has covered 513 thousand acres. Initial work has been completed on 39 percent of the total area included in the control units established by the Office of Blister Rust Control. Control work has been concentrated in the area from Sequoia National Park northward to Plumas National Forest, the optimum range of sugar pine in the Sierra Nevada. Some work has also been done in the Klamath and Lassen National Forests and in Lassen National Park.

The work already done has required 956 thousand man days of effort (to the end of 1947). The Office of Blister Rust Control estimates that, with the methods now in use, an additional 2-1/2 million man days will be necessary to complete the job on the entire 2,044,552 acres in control areas. Costs have risen rapidly from $4 or $5 per man day before the war to about $19 per man day in 1946. Although improved techniques now in sight may well result in some cost reductions, ribes elimination by present methods on the entire 2 million acres in present control areas might thus involve an additional expenditure of 45 to 50 million dollars.

Sugar Pine Markets and Prospective Requirements

Markets provide the basic economic justification for the production of any commodity. The 3.1 million acres of sugar pine types in California could grow a maximum of perhaps three hundred and fifty million feet of sugar pine timber each year if the necessary management and blister rust control effort were applied. But this would be a costly undertaking. Unless there is also some likelihood of a market for this amount of sugar pine, at a price sufficient to cover all of the real costs of production, to attempt to grow sugar pine on the entire area would be unwise. It would mean devoting time and money to the production of sugar pine when they could better be used elsewhere. Therefore a look at probable future market requirements for the species is needed as a guide to how much sugar pine we should attempt to grow.

Technical Basis for Market Preference for Sugar Pine

The position of sugar pine as a preferred wood for a number of important uses in the industrial and construction fields is due principally to its physical and working qualities; also, it has been available in large sizes clear of defects.

The wood of sugar pine is typically soft, even-textured, and stays in place well (that is, it shrinks and swells very little with changes in moisture content). It is easily dried with a minimum of degrade due to checking and warping. It works well under power or hand cutting tools. Although the wood is soft and light in weight, it has sufficient strength for the many uses to which it has been applied. Its even texture fits it well for moldings and carvings, and it can be nailed with a minimum of splitting. It provides a good base for paints and enamels.

In general its properties put it in a class with the other white pines, eastern (northern) white pine and western (Idaho) white pine, and the three are used for many of the same purposes. The pattern of lumber industry development in this country has been such that eastern white pine first came into use, then western white, with sugar pine last. Now, however, they are all found in the national market, and are considered as alternate woods for many uses.

Certain other woods, such as ponderosa pine, have gradually become competitive with sugar pine and other white pines for some uses. In some properties ponderosa pine is similar to or approaches the white pines, particularly when the softer, even-textured types of ponderosa pine are selected. It is usually available at lower cost and for some uses has received recognition. This trend may be expected to continue. But for such special uses as foundry patterns, musical and scientific instruments, boot and shoe findings, and special millwork, the properties of sugar pine remain superior, and the species may well retain its preferred position.

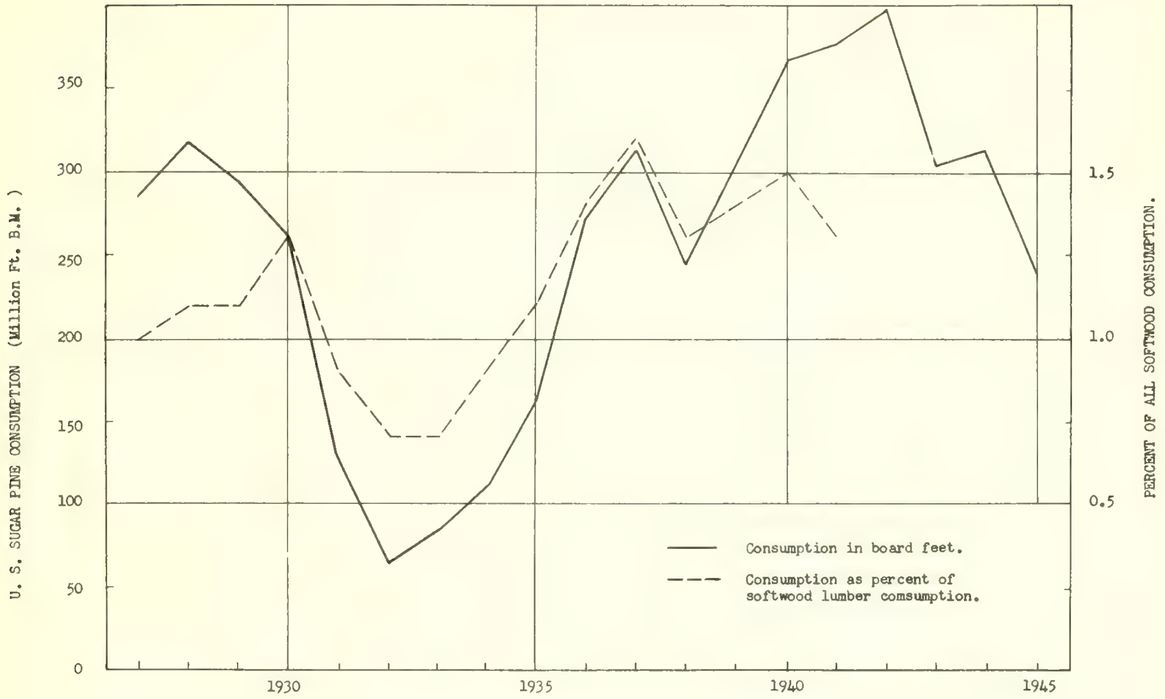


FIGURE 2. CONSUMPTION OF SUGAR PINE LUMBER IN THE UNITED STATES, 1927 to 1945.

Past Sugar Pine Consumption

Statistics on past consumption of sugar pine lumber are not available, but estimated consumption varies from about 64 million board feet consumed in 1932 to almost 400 million board feet in 1942, a six-fold increase (fig. 2). During the 19-year period for which estimates are available, consumption averaged 256 million board feet per year. Because of the pronounced influence of war conditions on recent lumber needs, it is difficult to establish any normal consumption trend from the data in figure 2. However, it is worth noting that in 1937, (a year of only moderate prosperity), sugar pine consumption was almost equal to that in 1928, a very prosperous year marked by heavy demand for lumber. The historical data thus seem to point toward a generally upward trend in total sugar pine consumption.

Although some variation occurs from year to year, sugar pine consumption normally has amounted to about 1.2 percent of all softwood use. In the producing area, of course, the relative importance of the species in the softwood market is much greater. But even there it is a secondary species from the volume standpoint, and special measures to grow sugar pine will find little justification on the basis of relative market volumes. The importance of sugar pine in the market depends rather on the uses to which it has special adaptation.

Principal Uses and Their Relative Importance

Sugar pine lumber has been consumed for (1) specialty uses, such as pattern making, sash and door manufacture, and instrument making, where the peculiar properties of sugar pine give it superior adaptability for the purpose; and (2) general uses, such as box manufacture, planing mill products, and light construction, where the special properties of sugar pine are considerably less significant. A general indication of the relative quantitative importance of these two types of use can be obtained by comparing sugar pine lumber used in manufacture in 1933 and 1940 with total sugar pine consumption (fig. 3). In each of the years for which information is available, specialty uses accounted for 32 percent of total consumption. As 1933 was a year of deep depression and 1940 one of pre-war prosperity, there is reason to feel that the proportions displayed by the data are fairly stable.

For the principal general uses, box manufacture and light construction, sugar pine comes into full competition with ponderosa pine as well as with other species, and its special qualities are of no particular advantage. Moreover, common grades comprise by far the greater proportion of the sugar pine consumed in these uses. As such, they are of below average unit value and, in most cases, are not even distinguished from ponderosa pine in the marketing process.

Thus, so far as two-thirds of the volume of sugar pine consumption is concerned, there is little to distinguish it from ponderosa pine. In contrast with Douglas-fir and true firs, sugar pine has some margin of technical superiority in this general market. But with proper methods of handling and with due recognition of the inherent characteristics of fir woods, this margin will probably narrow as time goes on.

Sugar pine is only a small element in this general market. Comparison of the 250 million board feet of sugar pine consumed in general uses in 1940 with the total size of the box lumber, planing mill, and light construction markets makes it clear that this species could only provide for a small proportion of the total consumption in these lines. The market is thus dominated by other species. Even though sugar pine commands a price premium for planing mill use, it seems safe to say that the general market would suffer little inconvenience or economic loss if sugar pine were replaced by ponderosa pine, or some other suitable species.

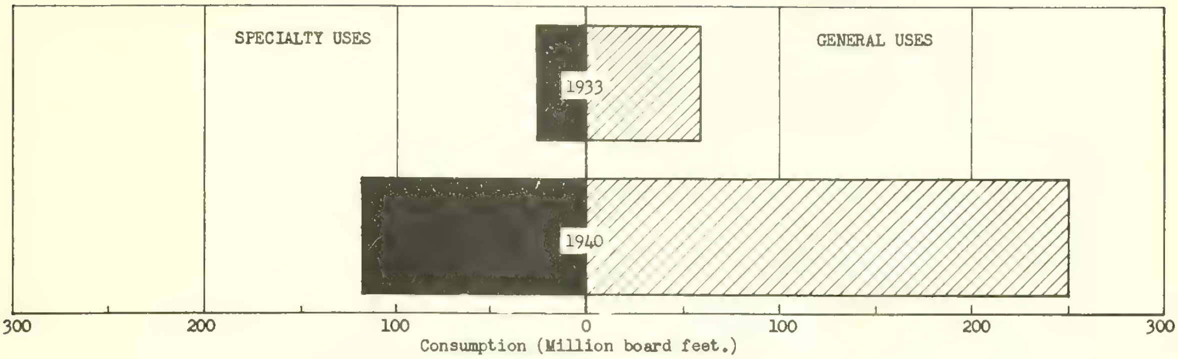


FIGURE 3. DISTRIBUTION OF SUGAR PINE LUMBER CONSUMPTION BETWEEN SPECIALTY AND GENERAL USES, 1933 and 1940.

Thus, the market which places primary reliance on sugar pine is the specialty use market. In 1940 about 120 million feet of sugar pine went into these specialty uses (table 3). Ninety-nine percent of this amount was used by six manufacturing industries: sash, doors, and general millwork; patterns and flasks; shade and map rollers; boot and shoe findings; scientific instruments; and musical instruments. Of these, millwork and patterns are the only volume consumers, taking over 93 percent of all sugar pine used in manufacture.

Table 3.- Major manufacturing specialty uses of sugar pine- 1940

Manufacturing use	Volume of lumber used in 1940 in M ft. b. m.				
	Sugar pine	Other white pine	Ponderosa pine	All other softwoods	Total softwood use
Sash, doors, and general millwork	90,239	53,009	852,126	648,327	1,643,701
Patterns and flasks	21,413	41,846	2,241	16,336[1]	81,836
Shade and map rollers	2,893	7,033	8,016	682	18,624
Boot and shoe findings	2,278	4,530	124	240	7,172
Scientific instruments	664	162	1,419	562	2,807
Musical instruments	655	158	212	3,815	4,840
Woodenware and novelties	245	1,139	3,662	6,305	11,351
Ship and boat building	244	3,174	899	56,851	61,168
Fixtures	204	2,001	8,780	18,798	29,783
Car construction and repair	158	1,522	1,361	485,825	488,866
Airplanes	105	157	24	7,466	7,752
All other manufacturing uses[2]	389	117,821	135,074	761,287	1,014,571
Total manufacturing use[2]	119,487	232,552	1,013,938	2,006,494	3,372,471

[1] Used largely for flasks.

[2] Excluding box, basket, and crate manufacture.

Source: U.S.D.A. Forest Service. Lumber Used in Manufactures - 1940.

Competitive Position of Sugar Pine in Different Uses

Although sash, doors, millwork and foundry patterns provided the principal manufacturing uses from the standpoint of volume, the picture is somewhat different when viewed from the standpoint of the relative importance of sugar pine to each of the industries in question (table 4).

Table 4.- Sugar pine and white pine consumption in selected manufacturing uses in relation to total softwood consumption - 1940

Manufacturing use	Total softwood consumption	Percent of total softwood consumption which was —		
		Sugar pine	Other white pines	All white pines
	M ft. b. m.			
Patterns and flasks	81,836	26.2	51.1	77.3
Patterns only (estimated)	65,000	32.9	64.4	97.3
Boot and shoe findings	7,172	31.8	63.2	95.0
Scientific instruments	2,807	23.7	5.8	29.5
Shade and map rollers	18,624	15.5	47.8	63.3
Musical instruments	4,840	13.5	3.3	16.8
Sash, doors, & general millwork	1,643,701	6.6	3.2	8.7
Woodenware and novelties	11,351	2.2	10.0	12.2
Airplanes	7,752	1.4	2.0	3.4
Fixtures	29,783	0.7	6.7	7.4
Ship and boat building	61,168	0.4	5.2	5.6
All other manufacturing uses*	1,503,437	negl.	7.9	7.9
Total manufacturing uses*	3,372,471	3.5	6.9	10.4

*Excluding box, basket, and crate manufacture.

The data bring out the fact that softwood lumber requirements for boot and shoe findings, patterns, and shade and map rollers are largely met by the use of white pine, and in each case sugar pine holds a substantial part of the market.

Of the 81.8 million feet of softwood used in patterns and flasks, 20 percent consisted of Douglas-fir, southern yellow pine and spruce, used primarily for flasks. Thus, for pattern work alone, only 65 million feet of softwoods were used and this need was met almost entirely by the white pines. Some ponderosa pine and a small amount of redwood also enter into pattern manufacture. Although some lower grade lumber of these species goes into flasks, their principal use here is in foundry patterns.

For scientific and musical instruments, and for woodenware and novelties, white pines supply less than 50 percent but more than 10 percent of total softwood use. They are thus major sources of supply for these industries even though they do not dominate the picture. Sugar pine is definitely favored over other white pines for instruments, but holds only 2 percent of the woodenware and novelty market. For sash, doors, and general millwork, white pines account for less than 9 percent of total consumption, but sugar pine appears to be in a preferred position with respect to other white pines.

In each of the other tabulated manufacturing uses sugar pine provides a negligible proportion of total softwood supply so far as the user industries are concerned. Some 5 million feet of eastern and western white pine went into fixtures and ship and boat building in 1940, but sugar pine supplied less than one-tenth of this volume to these industries.

It is worthy of note that, although a negligible percentage of softwood requirements for "All other manufacturing industries" was met from sugar pine, almost 118 million board feet of other white pines were used by this group in 1940. The principal items involved were western white pine for match blocks (74 million feet) and eastern white pine for caskets and toys (15 million feet).

The market pattern may be summarized by grouping together those industries where sugar pine is in a dominant, co-dominant, or subordinant position (table 5). About one-fourth of the tabulated volume of manufacturing use of sugar pine falls in the "dominant" and "co-dominant" groups. In view of the very definite expression of market preference for white pine reflected in table 4, loss of a sugar pine supply would undoubtedly be of serious consequence to users in these groups. The volume of such use can therefore be regarded as a rough measure of high priority market requirements for the species. In 1940 this amounted to 28 million board feet, practically all of it in Clear and Shop grades.

Table 5.- Classification of markets for sugar pine in manufacturing uses

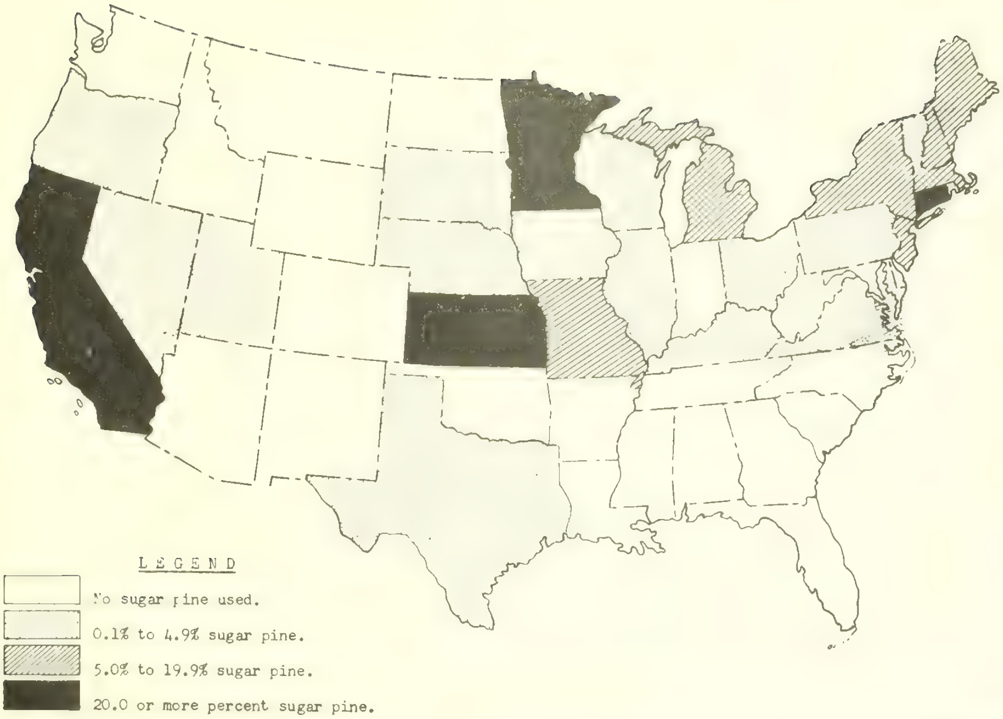
Type of market	1940 Consumption	
	Sugar pine	Other white pine
	Million ft. b. m.	
Sugar pine cominant	24.4	46.5
Sugar pine co-dominant	3.5	7.2
Sugar pine secondary	90.6	54.3
Sugar pine negligible	1.0	124.6
All manufacturing markets*	119.5	232.6

*Excluding box, basket, and crate manufacture.

Where sugar pine occupies a secondary position in the market it is more difficult to assess market "needs" for the species objectively. This sector involves primarily the use of sugar pine for sash, door, and general millwork manufacture. For this purpose, ponderosa pine and Douglas-fir are the dominant species, accounting for 52 percent and 22 percent of 1940 softwood consumption respectively. A closer examination of the use of sugar pine in this line of manufacture indicates that, despite its over-all secondary importance, sugar pine approaches a dominant position in particular market areas (fig. 4).

Sugar pine is in a very strong position in the Northeastern, Lake, and sugar pine producing states. In the Middle Atlantic and Central States it is of secondary importance. Elsewhere (except in Kansas) it is a negligible factor in the market. Using the same general criteria of dominance and co-dominance which were applied in deriving table 5, sugar pine appears in a co-dominant or better position with respect to the sash, door, and general millwork market in the following states: Minnesota, Connecticut, California, Kansas, Maine and New Hampshire.

These six states used 246 million feet b. m. of softwood lumber for sash, door and general millwork manufacture in 1940 of which 71 million feet, or 29 percent, was sugar pine. This figure may be regarded as measuring a second element in market needs for the species, of lower priority than that required for other manufacturing uses.



SUGAR PINE USE AS A PERCENT OF TOTAL SOFTWOOD LUMBER USE.

SASH, DOOR AND MILLWORK MANUFACTURE, 1940....

FIGURE 4.

Most of the sugar pine used in the manufactures discussed in the preceding paragraphs is of shop or select grades. It represents premium quality material. Production of the indicated quantities of these grades will, of course, generate corresponding quantities of lower grade lumber. On the basis of 50 percent grade recovery in shop and selects, the estimates of minimum market needs for specialty uses imply total minimum sugar pine needs of about 200 million board feet per year under 1940 conditions. Of this amount, 56 million board feet per year of output would have been required to meet the need for upper grades in the high priority manufacturing uses.

Supplies of White Pine Competitive with Sugar Pine

Although it has become of increasing relative importance, the supply of sugar pine lumber has always represented a minor portion of total white pine lumber supply when measured in quantitative terms. Despite catastrophic declines in its production, eastern white pine lumber output has always exceeded that of other white pine species, except for the decade 1931-1940 when western white pine was generally the leader (fig. 5).

As implied by the trend of the production data, however, eastern white pine seems likely soon to lose its leadership, even on a quantitative basis. Of the three major white pine species eastern white pine comprises less than a fourth of the remaining total saw timber supply, and western white pine about a third (table 6). Forty-four percent of remaining white pine saw timber is sugar pine. At 1944 rates of output, New England and Middle Atlantic States saw timber represented only 9.5 years cut. Comparable figures for other areas were: Lake States, 13.3 years; western white pine region, 55.7 years; and sugar pine region, 72.0 years. Although the relationship suggested by these figures ignores differences in regional growth rates and gives no credit for stands which are now of less than sawlog size, it seems highly probable that eastern white pine must lose production leadership within a relatively few years.

Table 6.- White pine saw timber supplies in the U. S. by species and location[1/]
1945

(Volumes in billions of board feet)

Species and location	Saw timber volume	
Eastern white pine:		
New England	6.3	
Middle Atlantic	2.3	
Lake States	2.6	
Other areas	1.3	
Species Total		12.5
Western white pine:		
North Idaho and Montana	12.6	
Elsewhere	4.5	
Species Total		17.1
Sugar pine.		
California	19.5	
Oregon	3.4	
Species Total		22.9
Grand Total -- All white pines		52.5

1/ Volumes in withdrawn areas, such as National Parks, have been excluded.

Source: U. S. Forest Service, Washington, D. C.

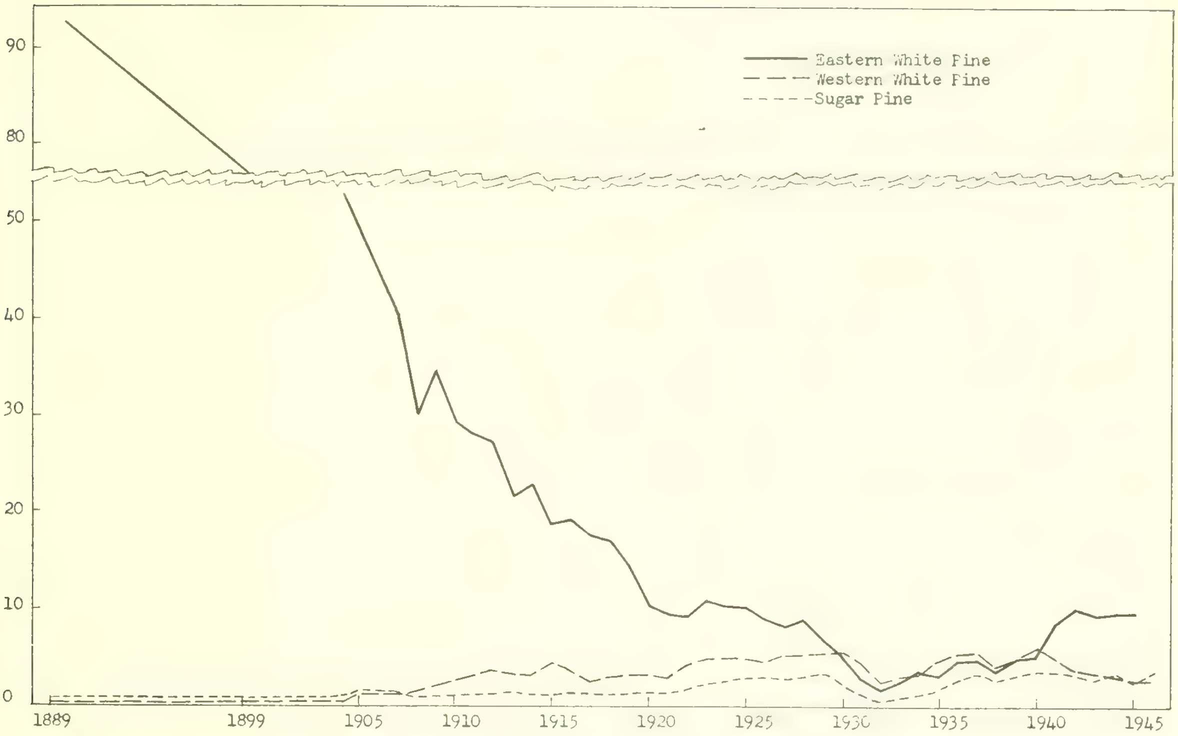


FIGURE 5. WHITE PINE LUMBER PRODUCTION IN THE U. S., BY SPECIES, 1889 - 1946.
Source: U. S. Census Bureau and Forest Service production surveys..

On a quality basis, sugar pine lumber supplies have been relatively much more important. Since the turn of the century, eastern white pine production has been increasingly from second growth and low grade residual stands. Data on percentages of output currently recovered in various lumber grades are not available for the eastern white pine regions. But a study of grade recoveries from butt logs of eastern white pine trees cut in New England in the middle 1930's showed that 86 percent of the board foot volume was in #2 Common or poorer grades. Only one and one-half percent of the total was in Select or better grades.

In contrast, grades and woods reports of the Western Pine Association indicate about 18 percent of western white pine and 22 percent of sugar pine is recovered in Select or better grades. In addition, about 2.5 percent of the lumber yield from western white pine and 27 percent of that from sugar pine is in Shop grades. If these percentages are representative, sources of white pine supply, by grade groups, looked something like this in 1945:

Grade Group	Percent of total supply from -			
	Sugar pine	Western white pine	Eastern white pine	Total
Selects	48	43	9	100
Shop	91	9	0	100
Common	9	16	75	100
All Grades	16	17	67	100

Thus, despite the fact that sugar pine ranked third among white pine species in total production, it dominated the market supply of Select and Shop lumber.

It seems clear that, so long as old growth stands hold out, sugar pine will remain the principal source of high quality material. But the situation may be less favorable for the long run period with which the problem of blister rust control is concerned. In this time, high quality stands of old growth timber in the West will have mostly been cut. All producing regions will be relying on second growth stumpage. Supplies of select white pine lumber will be limited to what can be produced through silvicultural practice. Shop grades, as now conceived, will probably no longer be produced in quantity.

Under such circumstances, eastern white pine may again play a more prominent role in the quality lumber market. The major factors which will determine the source of quality white pine timber will probably then be the relative rates at which white pine can be grown in different regions, the area available for such growth, the costs of silvicultural practices, and the extent to which different regions have maintained a high quality white pine growing stock.

Precise evaluation of the long-run comparative advantage of different white pine producing regions cannot be made. But certain regional differences can be recognized on the basis of the criteria listed above. Rates of growth are slower in the Northeast and Lake States than they are in California or in the western white pine region of Idaho. On the other hand, the areas in eastern white pine types account for about two-thirds of all white pine acreage in the United States (table 7).

Table 7.- Forest land areas in white pine types in the United States

Type and location	Area (Millions of acres)		Percent	
Eastern white pine types:				
Northeast	7.0		33.6	
Lake States	2.0		9.6	
Southern Appalachian	4.5		21.6	
Total Eastern white pine types		13.5		64.8
Western white pine types:		3.7		17.9
Sugar pine types:				
California	3.1		14.9	
Oregon	0.5		2.4	
Total sugar pine types		3.6		17.3
Grand Total All white pine types		20.8		100.0

Source: Office of Blister Rust Control

With respect to costs of silvicultural practices, sugar pine appears to be at a disadvantage because of difficulty in establishing it and of the need for continued treatments to free it from competition of other species. An additional element in costs stems from the fact that both eastern and western white pine can ordinarily be grown in stands which approach pure white pine type much more closely than can sugar pine. As costs of blister rust control are not materially affected by the proportion of white pine in the stand, costs per thousand feet of white pine produced will be less, other things being equal, for areas with a high percentage of white pine in the stand than for areas with a low percentage. This factor is probably offset only in part by heavier total volumes per acre obtained in sugar pine types.

Unlike the Northeast and the Lake States, California and the Inland Empire are still in a position to convert considerable portions of their white pine stands to high-quality forest growing stock at comparatively low cost. In eastern white pine areas, significant volumes of high-quality growing stock will only be achieved after heavy investment in stand rehabilitation and a very long period of waiting. In much of the West we still have a large volume of good growing stock on the ground and are in a position to add to it at comparatively low cost by proper methods of cutting in remaining virgin stands. This advantage is undoubtedly of paramount importance at the present time. But it is being dissipated so long as management practices in use in the woods fall short of those necessary to maintain a high grade sugar pine stand.

In sum, the long run outlook for white pine supplies indicates that because of favorable rates of growth and relatively undepleted condition of growing stock, the sugar pine region should be able to compete successfully with other areas of white pine production, provided existing old-growth stands are cut with the ultimate objective of maintaining sugar pine growing stock.

The Long-run Market Outlook

Lumber markets have always been characterized by a high degree of competition, both between different species of wood and between lumber and nonwood substitutes. Under such circumstances, continuity of supply is essential to maintenance of the market for any given lumber item. Reductions in the available supply of sugar pine will, if extended over a period of years, lead to greater adoption of other species or other materials by important segments of the present sugar pine market. Once lost, many of these markets would be extremely difficult to reestablish even if the supply of sugar pine improved. New patterns of user preference would have become established which would mitigate against, rather than favor, the use of sugar pine.

In other words, an important determinant of long-run sugar pine requirements will be the future course of sugar pine supplies. If these supplies can be maintained at present levels, future requirements will be larger than if a period of reduced supplies must intervene before the full effects of timber management policies can make themselves felt.

Adequacy of Prospective Sugar Pine Supplies

Existing sugar pine stands (table 8) appear barely adequate to maintain supplies through the necessary period of transition to a managed basis.

During the past two decades, an average of 250 million board feet of sugar pine has been cut each year. The existing available stand of almost 21 billion board feet could sustain this average cut for about 85 years. Detailed analysis has not been made, but it seems likely that future growth on young and residual stands would provide enough additional supply to maintain output at the 250 million feet per year level for at least an additional twenty years.

Table 8.- Sugar pine saw timber volumes

(as of January 1, 1945)
(in billion ft. b. m.)

	California	Oregon[1]	Total
Total saw timber	21.0	3.5	24.5
Available saw timber	17.4	3.4	20.8
Old growth stands	13.6	2.9	16.5
Young growth and residual stands	3.8	0.5	4.3

[1] Data supplied by Pacific Northwest Forest and Range Experiment Station.

Ability to maintain sugar pine supplies during the period required to build up a satisfactory sugar pine growing stock may thus be one of the most critical factors in determining future sugar pine requirements. There are numerous indications that saw-timber drain from California pine forests is likely to be maintained during the next few decades at considerably higher levels than those experienced in the past. If so, and if sugar pine comprises a normal proportion of this drain, the old-growth reserve of the species will be used up in considerably less than the 85-year period indicated above. Unless management programs are adequate to insure future supplies by the time the old-growth sugar pine stand has been removed, future market requirements may fall far below what current conditions would otherwise indicate.

The foregoing analysis implies the need for a blister rust control program designed to protect old-growth stands to the extent necessary to permit orderly liquidation of existing virgin sugar pine. If blister rust were not controlled, it seems probable that heavy losses of virgin timber would occur within 35 to 50 years. In order to avoid such losses it would be necessary to liquidate the old growth stand much more rapidly than would be consistent with perpetuation of sugar pine supplies. It is conceivable that such liquidation might be forced to the point where high grade sugar pine was being cut in greater volume than normal specialty markets could absorb.

The prospect of such a situation justifies enough blister rust control in old growth stands to keep damage to virgin timber below levels which would lead to accelerated liquidation. Such a program would probably involve careful selection of those areas of virgin timber which, at normal rates of cutting, would not be harvested until after significant blister rust losses had been incurred, and adoption of adequate control efforts in such areas. The costs of such a program could logically be charged entirely to the virgin stand.

Prospective Trends in Sugar Pine Requirements

The preceding analysis of sugar pine consumption has provided at least a rough basis for evaluating past minimum market needs for the species. When we look to the future, however, we are on much less certain ground, particularly when we take into view the lengthy period of sugar pine production which is an essential element in the blister rust problem. About all we can do is to point out the major factors which may cause changes in present levels of need, and indicate wherever possible the probable future trends of these factors.

An important variable affecting quantities of sugar pine needed at any time is the general level of economic activity and manufacturing output in the country. National income (adjusted to a dollar of constant purchasing power) provides a convenient index of the general level of economic activity. From 1860 to 1910 real national income doubled about every 20 years. From 1910 to the present it has doubled about every 30 years. In the light of this a further doubling between 1940 and the end of the present century would seem a conservative assumption, particularly in view of war-time experience with income and output. This would mean a minimum national income of $150 billion in 1940 prices to be achieved by the year 2000.

We cannot of course predict the effect of such an expansion in production on sugar pine markets. We can say with some assurance, however, that in the absence of compensating factors such a doubling of real income will have a very pronounced expansive influence on them.

Current trends in population growth and industrial development are tending to build up markets close to areas of sugar pine production faster than in areas of older economic development where the species is at a competitive disadvantage. There is every evidence to indicate that these trends will continue to operate for a long time to come. Insofar as they do, they will exert a further expansive influence on sugar pine markets.

Another factor likely to be important reflects the reduction in tree quality that will inevitably accompany liquidation of existing virgin stands. As more and more of the total sugar pine cut comes from second growth, the percentage of lumber recovered in upper grades will fall below current yields from old-growth timber (estimated at 50 percent). Future recoveries of upper grades are unlikely to exceed 35 percent of total cut. Under such circumstances a larger volume of standing timber will be required to meet given needs for high quality material. For example, to meet the "minimum 1940 market need" for quality material (estimated at 100 million feet) would then require production of 285 million feet of sugar pine timber, or 40 percent more than was required for production of the same amount of quality material in 1940.

Offsetting this are other trends which lead to a reduction in wood use. Two major trends of this sort should be considered. One involves the development and use of some new material to replace wood in a given use. Development of such substitutes depends on technological change and cannot be forecasted. About all we know is that the rate of such change as it affects use of sugar pine will certainly be influenced by relative prices for sugar pine lumber. If increasing scarcity of sugar pine leads to significantly higher real prices for the species than those experienced in the past we may well expect more substitution. On the other hand, in considering the likelihood of this possibility, it should be borne in mind that many potential substitutes are derived from sources of supply which are definitely limited. For example, as time goes on and our metal reserves are reduced, the tendency to replace wood by certain metals could conceivably be reversed. Because of its high quality sugar pine may be one of the first woods to profit from such a development.

A second factor which, in the past, has resulted in a decline in wood use, has been a shift in the market away from certain types of goods in which wood is an important component. Residential construction is an outstanding example. Slowing down of population growth simply reduced the aggregate size of the housing market. This factor seems likely to continue to operate as population stabilizes. However, there are few uses outside of the residential construction field where this type of thing seems likely to occur, and, as noted above, sugar pine provides only a small proportion of total lumber consumed in construction.

In summary, the long run demands for sugar pine will be largely the resultant of a powerful expansive force generated in response to normal growth of the national economy, an increase in prices due to reduced white pine supplies, and certain unpredictable but probable reductions in the market resulting from substitution and changes in the character of human wants. In the face of these conflicting trends, if an estimate of future sugar pine requirements must be made, it seems proper to place the figure somewhat above the estimated 1940 minimum needs. An estimate of 250 million board feet total annual needs by the year 2000 appears reasonable. Of this, perhaps 70 million feet, most of it high quality material, would be required to supply manufacturing industries where sugar pine now holds a key position in the market.

For a number of reasons, these appear to be conservative goals. Assuming that our estimate of general economic growth is approximately correct, the goals imply that only half as much quality sugar pine will be required for a given volume of economic activity, as was used in 1940. The goals make no allowance for the possibility that sugar pine may be called on to meet demands for needs now being filled by other white pine species, which may prove less able to compete under the handicap of blister rust control than sugar pine itself. They make no allowance for expansion of wood use in currently unimportant lines of consumption. Finally, they make no allowance for the very considerable market development which may take place in response to improved methods of wood utilization, and fundamental advances in wood technology.

Available evidence suggests that market demands for sugar pine would equal or exceed the 250 million foot level, under conditions of full employment, even in the face of an increase in real prices of sugar pine stumpage equal to a quarter or more of current values.

Trends in Sugar Pine Values

Stumpage Prices

Average stumpage price data for sugar pine and other species in California are available for most of the last quarter century. Caution must be used in interpreting such data, however, because average stumpage prices are based on quotations covering widely differing timber tracts. The prices reflect differences in quality and accessibility, as well as differences in basic values. For this reason, the data are primarily of use in studying long run relationships, where quality and accessibility factors may tend to average out. Year-to-year comparisons probably have little meaning.

Data on average prices of both private and public stumpage sales have been analyzed. As major movements of both sets of sugar pine stumpage values are usually consistent, the price series for public stumpage will be used in further analysis because more complete data are available covering such transactions.

Long run trends in values should be measured in terms of dollars of constant purchasing power. Price changes which merely reflect general inflationary or deflationary developments are not significant in evaluating the long run market outlook. Therefore, stumpage prices reported for National Forest timber sales were converted into "real" prices in terms of 19[illegible] dollars (Fig. [illegible]).

The year-to-year variations in average real stumpage prices have been very large. But it should be remembered that these are due in part to year-to-year variations in quality and accessibility of timber sold. Despite these fluctuations, the data give a definite indication of an upward trend of about 8 percent per decade in the real price of sugar pine.

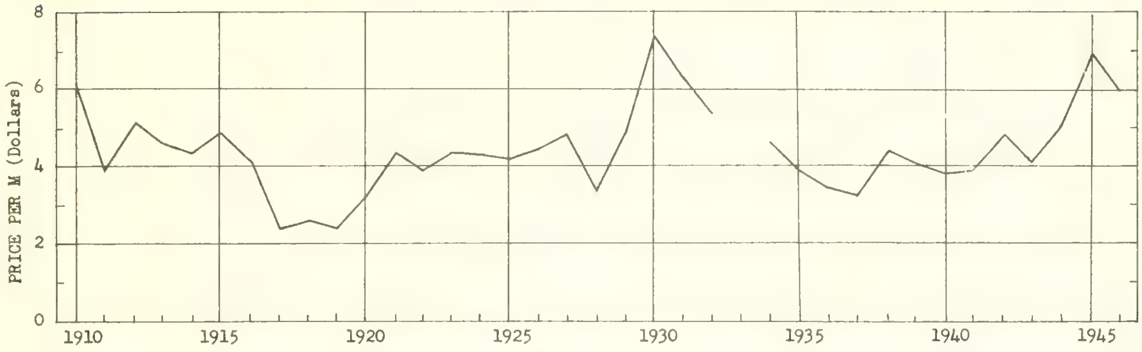


FIGURE 6. WEIGHTED AVERAGE ANNUAL SUGAR PINE STUMPAGE PRICES IN CALIFORNIA NATIONAL FOREST TIMBER SALES, 1910 - 1946.
(Adjusted to dollars of constant purchasing power. Base Year = 1926.)

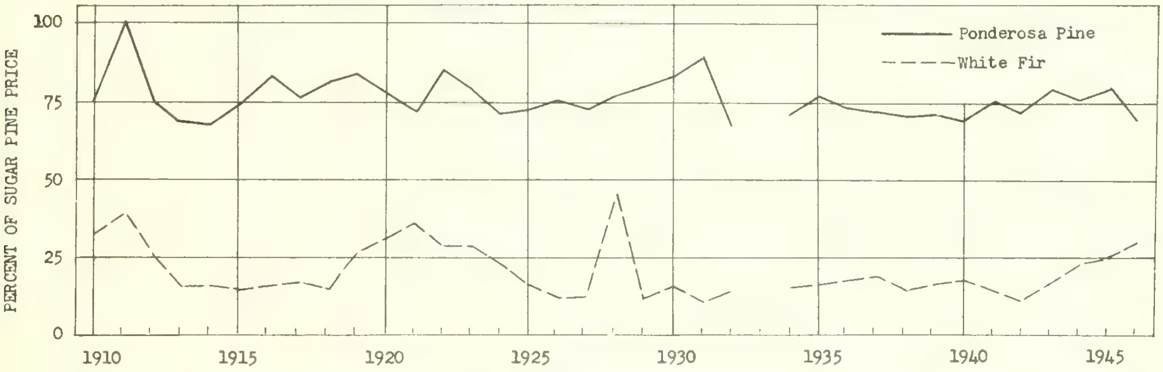


FIGURE 7. AVERAGE ANNUAL PONDEROSA PINE AND WHITE FIR STUMPAGE PRICES AS A PERCENT OF SUGAR PINE PRICE.

From the standpoint of problems of sugar pine management and blister rust control, the amount and trend of the stumpage price differentials between sugar pine and other species competing for the same site is just as important as the general trend of stumpage prices as a whole. To avoid the bias which enters into a simple comparison of weighted average prices, the data for 248 National Forest timber sales of mixed species including sugar pine, covering 1.5 billion feet of sugar pine timber, were analyzed in the following way. For each sale, stumpage prices of each species were expressed as a percentage of the stumpage price of sugar pine applicable to that sale. Annual average percentages were then calculated by weighting the percentage for each sale by the volume of sugar pine included in the sale. The resulting figure expresses the average percentage relationship between sugar pine stumpage values and those of other species (fig. 7).

For the 37-year period 1910-1946 the observed stumpage price differentials have been rather consistent. (In the years of widest deviation from trend, such as 1911, 1914, 1928 and 1931, relatively small volumes of sugar pine were sold). For all 248 sales in the period, the ponderosa pine stumpage price averaged 76.5 percent of the sugar pine stumpage price. Fir averaged 20.8 percent.

There was a small but recognizable tendency for the differential favoring sugar pine to increase with respect to both ponderosa pine and fir. From 1910 to 1919, ponderosa pine prices averaged 78.3 percent of sugar pine, but by 1940-1946 they averaged only 74.6 percent. During the same interval, the corresponding percentages for fir fell from 20.5 to 16.9. In connection with the latter species it should be noted that from 1925 to 1942 almost all National Forest timber sales were made at the minimum statutory price of $.50 per M. This has the effect of increasing the ratio of fir to sugar pine prices during this period above what it would have been in the absence of a floor under fir prices.

Although the evidence is thus fairly convincing that the stumpage price differential between sugar pine and other species competing for the site has widened, the rate at which the spread has increased in the past has been so small as to be of little practical significance. In the case of fir, the last four years have seen a steady reduction of the differential, but it may be premature to interpret this as a reversal of the long time trend.

Lumber Prices

The average value of lumber at the mill has been tabulated annually by the Census Bureau for major species cut in California since 1906. Such average values are much less subject to bias than average stumpage prices and are therefore useful as an index of changes in lumber prices.

On the basis of such data (fig. 8), sugar pine lumber values rose a little faster during the period 1906-1943 than did those of associated species. Comparisons of 5-year average values for the periods 1906-1910 with those for 1939-1943 showed an increase of 98 percent for sugar pine, 89 percent for ponderosa pine, and 92 percent for white fir.

The pattern of price movements was much the same for all three species. All three rose rapidly from 1916 to 1920 and then declined more slowly until 1933. During the 1920-1935 period sugar pine values were better maintained than were those of the associated woods. By 1935, sugar pine was still almost 75 percent above its pre-war value. Ponderosa pine was up only about a third and white fir a quarter.

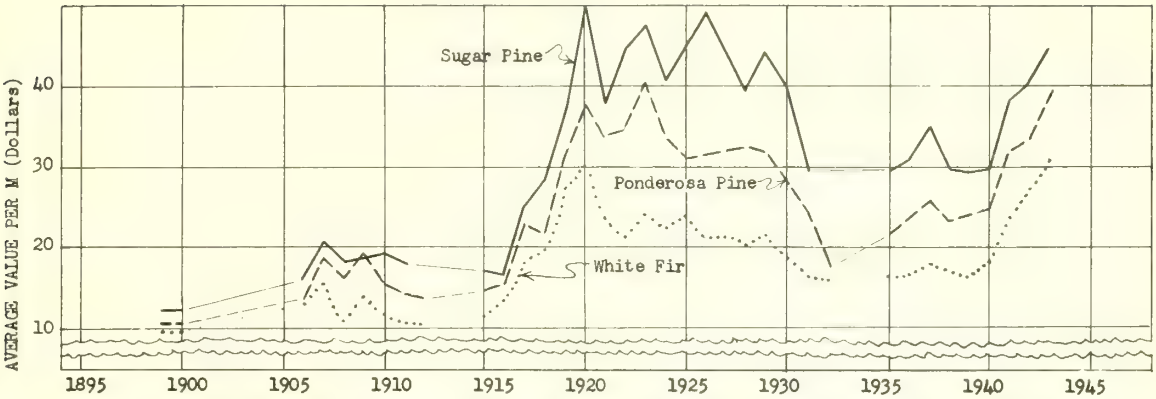


FIGURE 8. AVERAGE VALUE AT MILL OF SUGAR PINE, PONDEROSA PINE AND WHITE FIR LUMBER IN CALIFORNIA, 1899 to 1943.

However, the price rise following 1939 affected the latter two species more strongly than it did sugar pine, so that by 1943 pre-World War I value relationships between the three species had almost been restored.

Lumber value differentials between sugar pine and other species showed significant movements from 1906 to 1943. The average value of ponderosa pine lumber declined from about 90 percent of sugar pine value in 1906 to about 65 percent in 1925. Since the latter year the trend has been toward a narrowing differential between the two species. During World War II ponderosa pine values held steady at about 85 percent of sugar pine lumber values. Differentials between white fir and sugar pine declined still more sharply in the 1906-1925 period. White fir values were about 80 percent of sugar pine values in 1906, but declined to less than 45 percent by 1925. Since then the differential has displayed the same upward trend shown by ponderosa pine. During the war the average value of white fir lumber had recovered to almost 70 percent of that of sugar pine.

The lumber value differentials display somewhat the same trends as did the stumpage value differentials. The principal difference is that white fir stumpage prices tend to bear a much smaller ratio to sugar pine stumpage prices than do lumber values of the two species. This is easily explained on the basis of the residual character of stumpage values. It probably means that further increases in the general level of stumpage prices will lead to a narrowing of the percentage differential between fir stumpage and pine stumpage, even though lumber prices of the various species retain their present relative positions.

The Long Run Outlook for Stumpage Prices

The opinion of sugar pine producers and of others well informed in the field provides the best guide to the long run price and market outlook for sugar pine. A recent sampling of such opinion showed agreement that the trend of real prices of upper grades of sugar pine will probably be upward for a long time to come. The operators also anticipated increases in the real price of common grades, although these were expected to be less than the increases for clear lumber. It is expected that, grade for grade, prices of sugar pine uppers will rise more rapidly than those of the associated species.

Extension of the long run trends of real lumber values discussed in the preceding section would support this consensus of industry opinion.

Operators also expected a continued general rise in·stumpage prices. There was a diversity of opinion as to whether sugar pine would rise more rapidly, at about the same rate, or less rapidly than other species. Others felt that, as virgin timber is cut out, sugar pine would lose some of its present price advantage over other species because of a general decline in the quality of stumpage.

The historical stumpage price data previously cited provide good evidence in support of this anticipated further increase. They also suggest that the question of changes in stumpage price differentials between sugar pine and associated species may be of little practical importance because of the very slow rate at which such changes have taken place in the past.

On the basis of this evidence, it seems reasonable to conclude that the future price relationships involved in growing sugar pine may be more favorable than those which prevail at present. It suggests that, by the time managed stands of young sugar pine mature, returns will be sufficiently high to offset management costs substantially above those which would appear justifiable in the light of current stumpage prices.

The Cost Elements in Growing Sugar Pine

Detailed records of costs of growing sugar pine, based on proven silvicultural practice are not yet available. But the weight of past experience indicates that careful treatment is essential if a crop of sugar pine is to be established, protected from natural hazards, and carried through to maturity. Intensive management must go hand in hand with intensive protection against blister rust if satisfactory sugar pine yields are to be obtained at reasonable cost.

Management Costs

In contrast with management of other species competing for the site, sugar pine management may prove more expensive both because of greater difficulty in securing satisfactory regeneration, and because of the need for additional cultural measures.

Where seed trees are used, sugar pine regeneration may be more costly than that of either ponderosa pine or the firs because seed trees must be larger, with consequent greater carrying charges. In addition, for adequate stocking of an area of given size, more sugar pine seed trees must be left because fewer seeds are borne per tree, seed flight range is shorter, and a smaller proportion of seed escapes natural hazards to germination. Planting with sugar pine is also likely to be more expensive than planting with ponderosa pine because of greater costs of seed and planting stock, and of lower field survival. Additional expenditures will probably be necessary to protect sugar pine seed from squirrels and other rodents, which display a preference for sugar pine seed.

Where sugar pine is associated with white fir, young sugar pines will have to be released from competition to insure retention of sugar pine in the stand until time of harvest. Because sugar pine height growth is less rapid than that of white fir, two extra thinnings will probably be required to maintain sugar pines in a dominant position until they are mature.

Even in well-stocked stands, sugar pine clears its trunk of branches by self-pruning only after a long period of time. As the value premium from sugar pine is largely based on the production of Shop and Select grades of lumber, pruning is essential in order to secure a reasonable proportion of knot-free lumber at maturity. Unless pruning is done, the other extra expenditures involved in establishing and protecting the species will be largely wasted in the production of common boards. We have already seen that common grades of sugar pine are unlikely to command any value premium over comparable grades of ponderosa pine, which can be grown at much less expense.

The Impact of Blister Rust Control Costs

Before the war, the cost of ribes eradication, although variable, averaged from four to five dollars per acre. But since 1940 increasing wages and price levels, shorter work weeks and operating seasons, generally lower quality and less productive labor, and higher standards of camp construction, sanitation, and equipment have all tended to increase costs. By 1946, the average cost of ribes eradication in California was almost $16 per acre worked.

But the behaviour of blister rust control costs cannot readily be grasped in terms of broad averages. Any disturbance to the ground, such as logging or fire, causes a large and immediate increase in the ribes population, the size and persistence of which vary with the site and other factors. Thus, all areas under forest management suffer disturbances from time to time which result in ribes regeneration and require intensive ribes suppression work. Costs for any given area will depend on the number, timing, and severity of such fire and logging disturbances, and on local biological factors such as site and type, which condition the ribes response.

For a given forest type, site, and total timber stocking, the costs per acre of blister rust control are largely independent of the amount of sugar pine which is present. Thus, total control costs will be about the same regardless of whether the stand contains 5 percent or 50 percent sugar pine if other conditions are identical. As the entire cost of control must be charged to the sugar pine yield, it is apparent that the degree of sugar pine stocking will have a profound effect on the cost per thousand board feet of sugar pine production.

Moreover, opportunities for reducing unit costs by increasing the percentage of sugar pine in the stand are distinctly limited by the silvical possibilities of the forest types in which sugar pine occurs. Although it is possible that with intensive management practices the sugar pine component may be raised above 35 percent of the total stand, without intensive management the proportion of sugar pine will undoubtedly be much less.

Some idea of the significance of this factor for economical sugar pine production can be gained from the following illustration. A rough estimate indicates that for high site sugar pine—fir areas, a cash outlay of about $55 per acre (at current levels of cost) may be required for blister rust control measures over a 100 year period of converting the old-growth stand into a managed growing stock. This expenditure will, of course, be spread over several decades. A considerable part of it may well be considered as a permanent investment in land improvement and not subject to depreciation. But a substantial proportion still must ultimately be charged to the new sugar pine crop. Total yields from such an area may approach 55 M board feet per acre if adequate stocking has been maintained. If only 35 percent of this yield is likely to be sugar pine, the cash outlay for blister rust control will represent $2.85 per M of sugar pine produced.

Most of the existing cutover area in sugar pine types shows much less than 35 percent sugar pine. Detailed statistics are lacking at present, but on many extensive areas in cutover sugar pine type sugar pine stocking is known to average less than 10 percent of total stocking. If only 10 percent of the total yield were to be realized in the form of sugar pine, the cash outlay for blister rust control would be increased to $10 per M of sugar pine produced.

Similarly, stocking will have a direct effect on unit costs. The blister rust control charge per M will be much greater in a stand that is only half stocked than in one that is fully stocked. Here the effect of reduced stocking on costs per M is intensified by the fact that blister rust control is generally more difficult to achieve in stands where the timber canopy is not complete. Openings in the forest provide favorable conditions for establishment and growth of ribes bushes and insofar as low stocking implies the presence of such openings, per-acre control costs are likely to be significantly higher than in fully stocked stands. Per-M costs of blister rust control in understocked stands are therefore likely to be pyramided, higher per-acre charges being incurred on top of the smaller per-acre volumes over which charges can be spread.

Site has two opposed effects on costs. Yields rise rapidly with increases in site quality. Costs can therefore be spread over a larger volume on high sites, and per-M costs will tend to be lower. On the other hand, high site favors the growth of ribes and total costs on such areas are likely to be higher than on low sites. The effect of site variation on costs per M will thus depend on the particular yield and ribes growth at each local situation.

Differences in forest type also have two mutually offsetting effects. As has already been shown, ponderosa pine normally brings 75 percent or more of the stumpage return obtained from sugar pine, while true firs bring only about 25 percent as much. This suggests that blister rust control can be undertaken more advantageously in those timber types where fir is the alternative to sugar pine than it can in types where ponderosa pine is the alternative. This is so because the alternative to growing sugar pine in sugar pine—ponderosa pine types (growing more ponderosa pine) is more attractive than the alternative available in sugar pine—fir types (growing more low-value firs). But this differential is offset, at least in part, by the fact that total control costs are likely to be much less in sugar pine—ponderosa pine types than in sugar pine—fir types.

The preceding discussion emphasizes the fact that costs of blister rust control and sugar pine management behave in a very complex fashion in response to differences in forest conditions. Decisions as to where sugar pine culture is economically justified must therefore be based on a careful study of behaviour of costs under the variety of site, composition, density conditions, and management methods that are encountered in the woods.

Summary

A preliminary study of economic aspects of blister rust control and sugar pine management, based largely on existing and readily available data, yields the following information.

1. The sugar pine resource in California consists of some 3.1 million acres of land in sugar pine types, plus an additional 2.2 million acres in other types containing some sugar pine. The area is almost equally divided between public and private ownership. About 800 thousand acres of sugar pine type is on high site land (site I-175 or better), almost all of it in the western Sierra Nevada. The total sugar pine timber stand in California amounts to 21 billion board feet of which about 17-1/2 billion is considered available for commercial use. Fifty-six percent of this volume is in public ownership. Over three-fourths of the available sugar pine is in old growth stands, with only 1.5 percent of the total supply in the form of young growth stands.

2. Since 1933, protection of this resource from blister rust has been carried on on a large scale under the leadership of the Office of Blister Rust Control, in cooperation with numerous Federal, State, and private agencies. At present 2.0 million acres of sugar pine type are included in blister rust control areas, and initial eradication of ribes has been completed on 39 percent of that acreage. Control effort has been concentrated in the optimum range of sugar pine occurrence. Work done to date represents about 27 percent of that estimated as necessary to secure and maintain control by present methods on areas now included in control units. Average costs in 1946 amounted to about $16 per acre worked, some three times pre-war levels of cost. The increase was due largely to increased costs of labor and materials and lower levels of worker productivity. New methods of ribes suppression hold some promise, however, for future reductions in cost.

3. Sugar pine consumption in the United States averaged 256 million feet b. m. from 1927 to 1945. A peak of 400 million feet was achieved in 1942 and current use is well above the 19-year average. About one-third of this total is ordinarily used for specialty purposes including sash, doors, millwork, patterns, and other forms of manufacture. The remainder goes largely into box manufacture and light construction uses. Market dependence on sugar pine is clear cut for pattern making and boot and shoe findings, certain types of instruments, and shade and map rollers. In sugar pine producing states, in the Lake States, and in the Northeast the species is a major source of supply for sash, door, and millwork plants. Elsewhere, and in other uses, sugar pine is a very minor element in total softwood lumber supply. The future trend of sugar pine lumber requirements will be the resultant of several conflicting factors. As nearly as these can be appraised at present, minimum total future requirements should not be far different from the quarter of a billion board foot average annual consumption of the past two decades. Of this, some 75 million board feet of output will be required annually to meet needs of high priority manufacturing uses.

4. Sugar pine stumpage values displayed a general upward trend from 1910 to 1945 amounting to an increase of roughly 1 percent

per year. The differential between sugar pine values and those of other species has shown little significant change. Ponderosa pine stumpage values were about 75 percent those of sugar pine during the 1940-1945 period. White fir values were less than 20 percent of sugar pine values. Available evidence points to a continued, and possibly more rapid, long run rise in relative sugar pine stumpage values, as supplies of high grade wood become increasingly scarce. Because stumpage values currently amount to less than 15 percent of lumber values at the mill, stumpage prices could increase two- or three-fold without leading to prohibitive rises in the average value of sugar pine lumber. Hence, the anticipated rise in stumpage values should not have major adverse effects on markets for sugar pine lumber.

5. The costs of sugar pine protection and management, per M board foot produced, are extremely sensitive to variations in site quality, stand composition and density, and age of stand. They are too variable to permit of any ready generalizations. Ultimate determination of the margin for economical sugar pine production and blister rust control will depend on careful study of the way in which control costs vary as between the different stand conditions encountered in the sugar pine zone. When the market and price data presented in this report are supplemented by the results of such cost studies, a sound basis will be available for defining sugar pine management units on economic grounds.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director

No 59 January 1949

DEP[illegible]
THE UNIV[illegible]
SE[illegible]

MAKING PAPER TUBES FOR PLANT PROPAGATION

By

Emery F. Kimbrough

A growing interest is evident in the use of paper tubes for culturing ornamental plants or tree seedlings. Several advantages are claimed for this type of container. In the first place the tubes require less space, less potting soil and water, and are lighter in weight and easier to handle than the gallon cans commonly used for this purpose. Then, too, the roots are directed downward; when outplanted the lower roots are twelve inches deep rather than six inches as when plants are cultured in cans. Finally, the seedling and its container may be planted together, saving time and avoiding injury to the roots; however, some species respond better if the container is removed.

Tubes can be made from heavy building paper and then dipped in hot paraffin, from waxed stock such as that used for milk containers, or from light weight tarred roofing paper. The latter is somewhat toxic to some plants, particularly when the tube is planted with the seedling, and for this reason has not been entirely satisfactory for general use. In any case the plants should usually be outplanted at the end of one year.

The method described here is used in making tar-paper tubes at the Institute of Forest Genetics at Placerville, California. The tubes have been used primarily for propagating cork-oak seedlings, but they have also been used for propagating pine seedlings and several species of ornamental plants. Slight modification of the method will adapt it to use with other materials than tar paper. Inquiries received regarding the method for making tubes have convinced us that this description would be welcomed by many plant propagators.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Materials and Equipment

Roofing paper in 100 foot rolls 36 inches wide.

Dispenser for 36-inch roll paper with two knives mounted to cut the paper into three 12-inch strips as it is pulled from the roll (see fig. 1)

Table 12 feet long, 4 feet wide and 40 inches high, with 9 jigs (guides) mounted across the table at 12-inch intervals (fig. 1).

Work bench 8 feet long, 3 feet wide, and 3 feet high with 15 x 15-inch shelf to which is attached a piece of 2-inch iron pipe extending 15 inches beyond the edge of the shelf (fig. 2). A tension clamp 1-inch wide made of spring steel is attached to the shelf 1 inch from the edge (Detail "A" fig 2)

Container for heating cement and tablespoon for spreading it.

Hot plate to keep the tar or roofing cement hot.

Paring knife or linoleum knife with short, sharp blade.

Procedure

When the listed materials are properly assembled the tubes are constructed as follows:

A roll of paper is placed in the dispenser and pulled off to the full length of the table, being ripped into three strips 12 inches wide by the mounted knives as it is pulled from the dispenser. The strips of paper are then in position on the jigs and may be cut into 12-inch squares, three at a time by drawing a knife along the jigs that cross the table.

When enough tar-paper squares have been cut the process continues as follows.

A square of paper is placed on the shelf under the spring steel clamp, the edge of the paper being aligned with the edge of the shelf (fig. 3, A). A 1-inch margin of the paper is then exposed between the edge of the shelf and the clamp. From end to end, along the center of this margin of paper a tablespoon of hot tar is poured in a line about one fourth inch wide. The opposite edge of the paper square is then brought over and placed against the outer edge of the clamp to form a cylinder, and the thumbs of both hands press the two edges together sealing the ends of the seam with the cooling tar.

The partly finished tube is then pulled from under the spring clamp and placed over the piece of 2-inch pipe, the seam up (fig. 3, B). The seam is seale by running the fingers along it with considerable pressure. By this time the ta or cement will have cooled enough so that the finished tube may be removed from the pipe and used or stored.

A 100-foot roll of paper will make 300 tubes.

An experienced workman can make 125 tubes or more per hour.

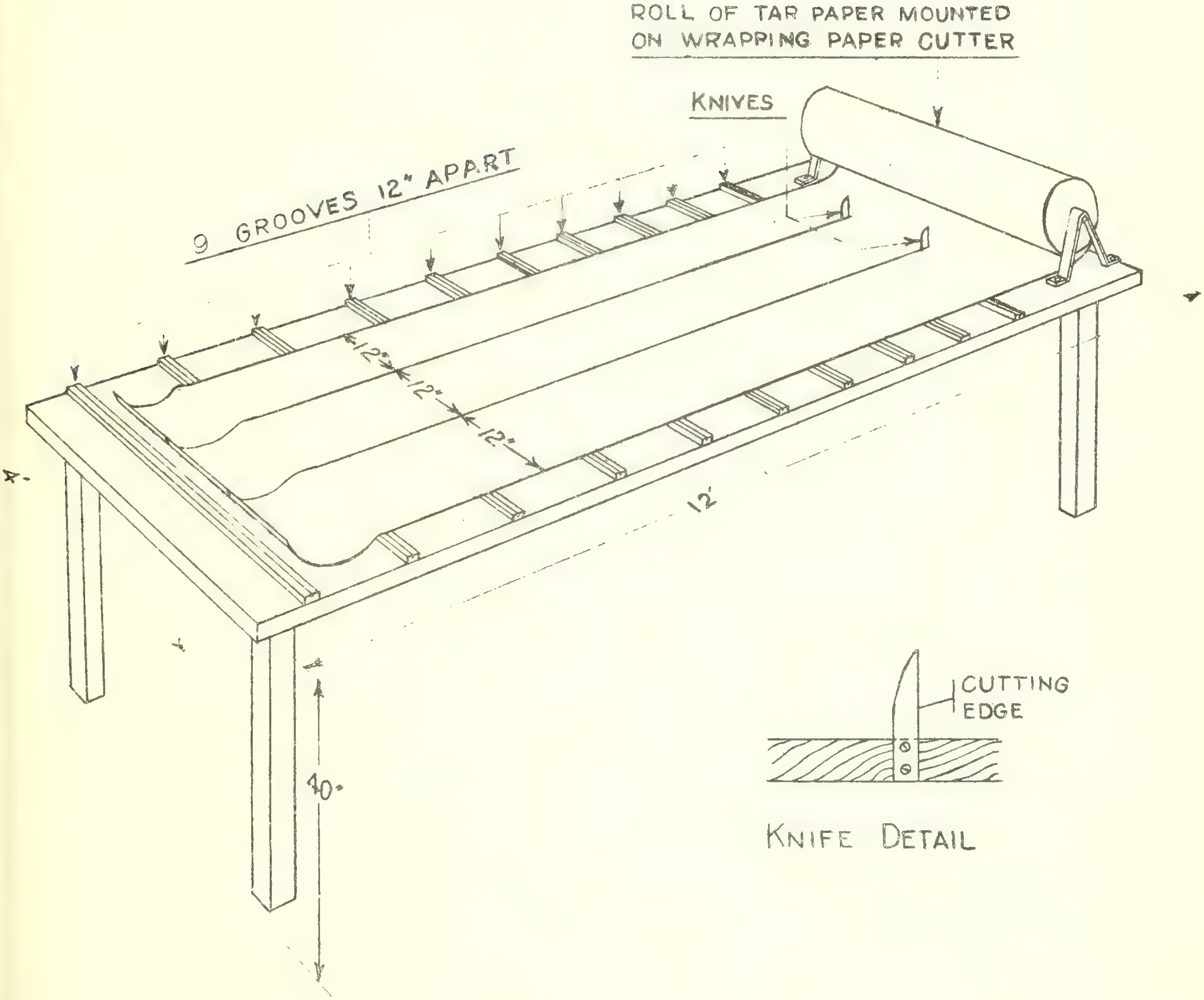
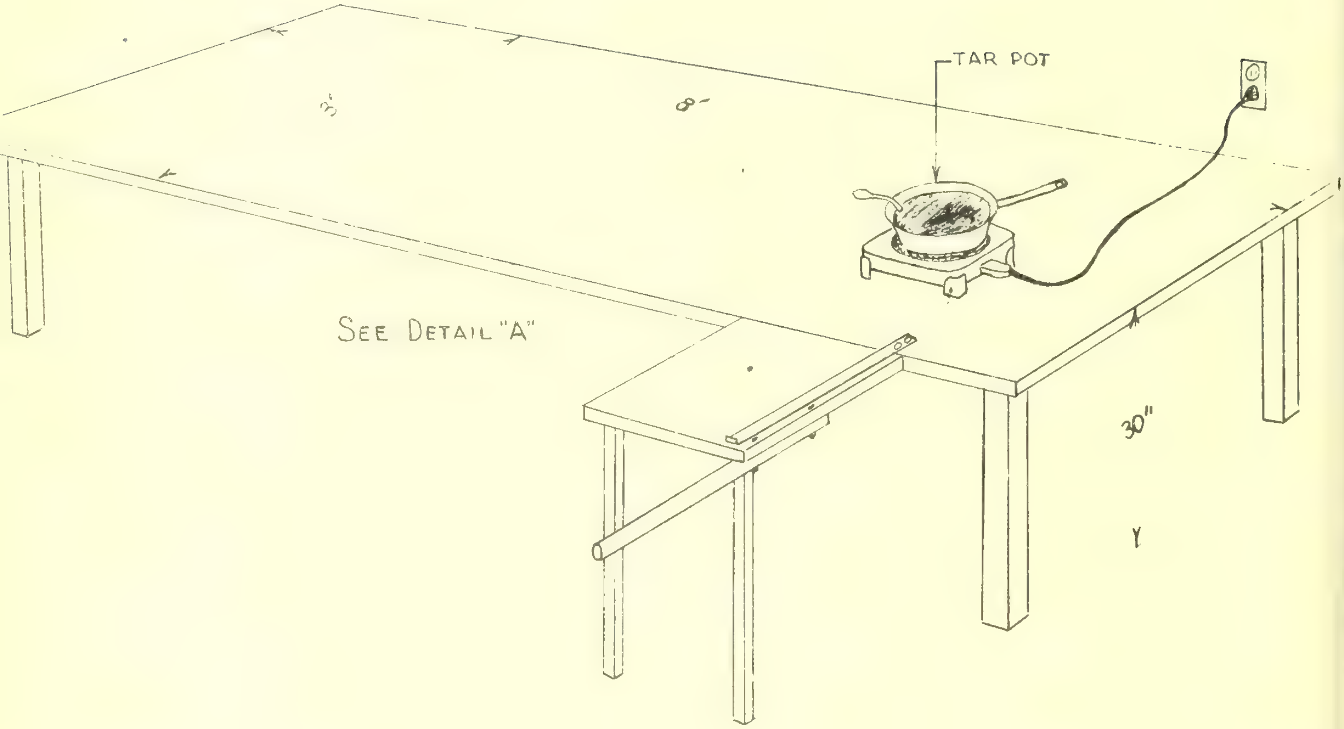

ROLL OF TAR PAPER MOUNTED ON WRAPPING PAPER CUTTER
KNIVES
9 GROOVES 12" APART
12"
12"
12"
12'
40"
CUTTING EDGE
KNIFE DETAIL

Fig. 1


TAR POT
3'
8'
SEE DETAIL "A"
30"

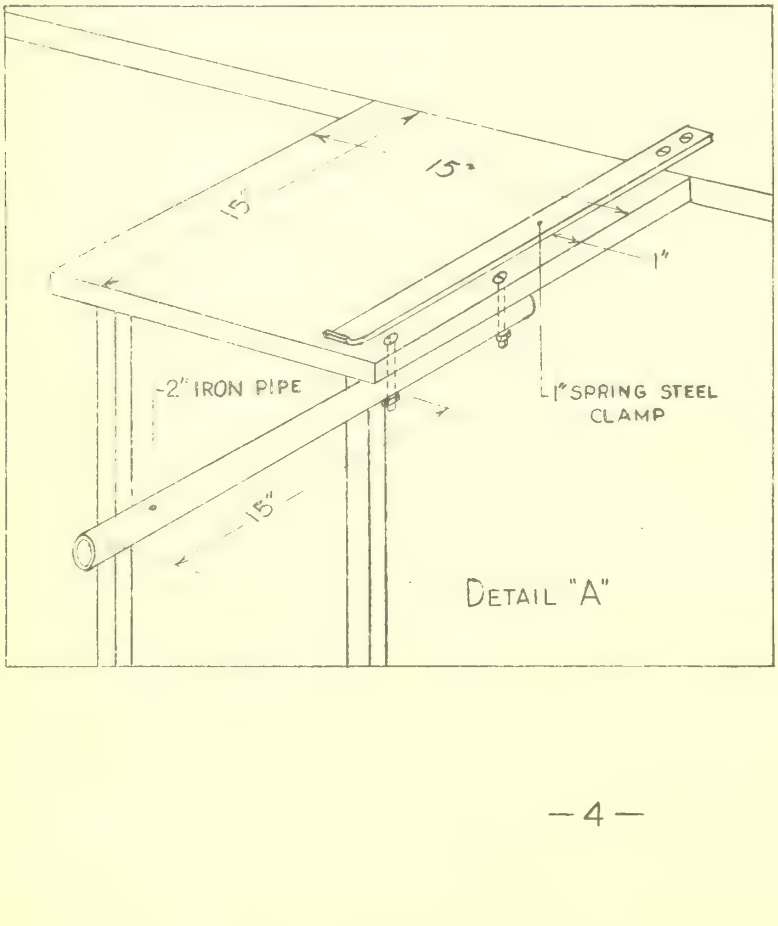
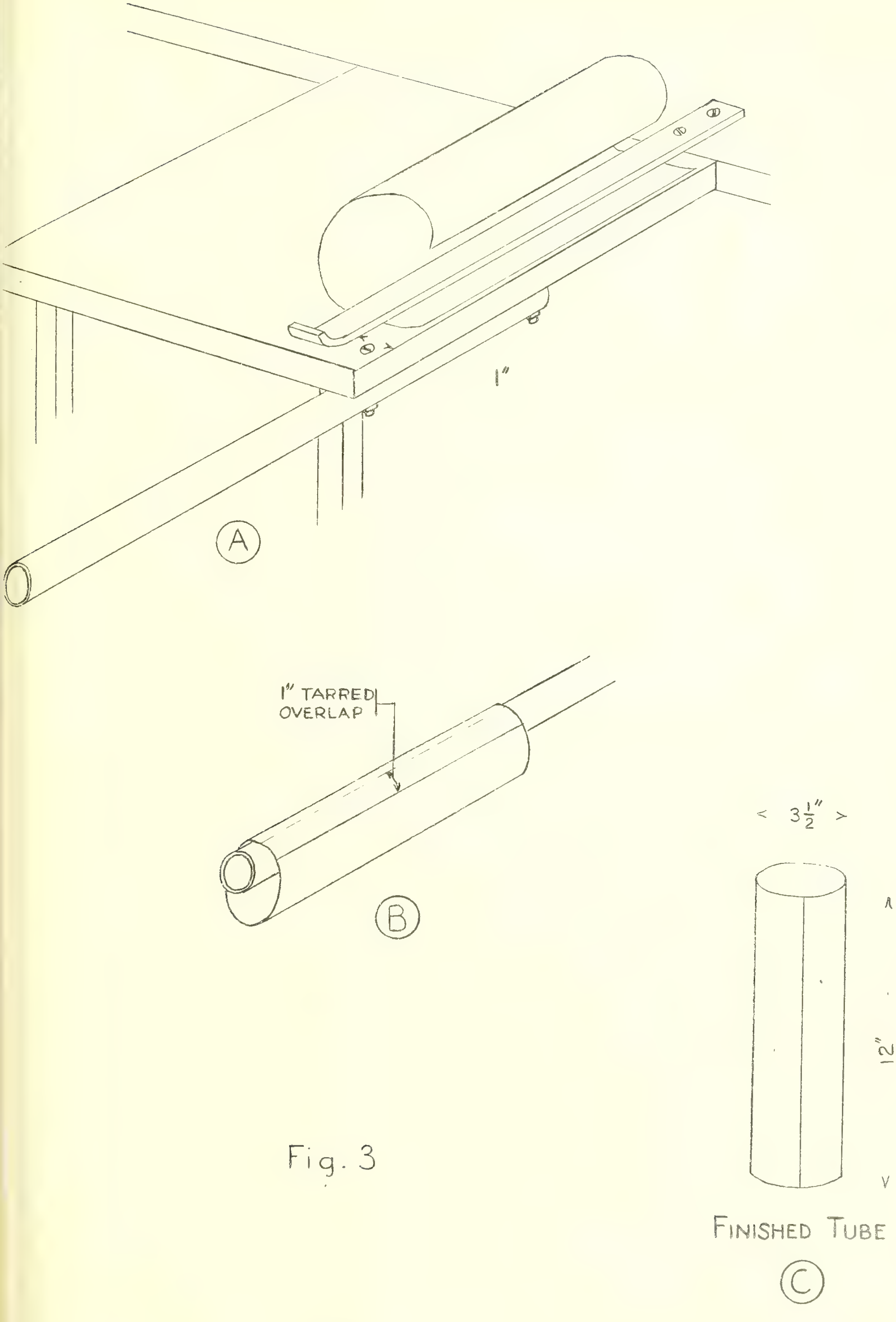

15"
15"
1"
2" IRON PIPE
1" SPRING STEEL CLAMP
15"
DETAIL "A"

Fig. 2



FINISHED TUBE

Fig. 3

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

Research Note No. 62 July, 1949

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

SEASONING CALIFORNIA BLACK OAK

By Harvey H. Smith

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Introduction

The forest industry of the Pacific Coast is based on the utilization of softwood species, and little attention has been paid to the several native hardwoods. Some of these hardwood species appear to be suitable for general commercial use. One of the most promising is California black oak (Quercus kelloggii), which grows extensively in Oregon and California, and is particularly abundant on the west slopes of the northern Sierra in canyons within the ponderosa pine belt at 3,000 to 5,000 feet elevation.

California black oak has been cut on a limited scale for manufacture into lumber and flooring. These few efforts in the past have usually met with only limited success because the operators often did not produce the quality and size of lumber to meet the needs of the prospective buyers and because it was usually poorly manufactured and seasoned. Another reason for the slow development of the hardwood industry on the Pacific Coast is the scattered occurrence of most of the hardwood species. They are decidedly scattered when compared to the softwoods growing in the same general area, but look considerably more promising when compared to many of the hardwood stands of the east from which the present supply is cut. The western hardwoods are more difficult to season[1] than the several species of softwoods with which they are associated, and require special methods of manufacture and seasoning.

The present lack of development of the Pacific hardwoods indicates the need for more information about these species. The purpose of this study was to develop a practical, effective seasoning procedure for California black oak so that its utilization can be put on a more sound basis. These drying experiments were carried on in cooperation with the Diamond Match Company at Stirling City, California. The tests were conducted in two phases, one for air drying and another for kiln drying procedures.

Test Material

Black oak logs were cut early in June on a logging area near Butte Meadows, located in Butte County in the northern Sierra Nevada region of California. The logs represented a wide range of both size and quality. Some logs of marginal size and quality were selected to determine the yield from such material. The total log scale was about 18,000 bd. ft.; the number of large defective logs and small poorly-formed logs made an accurate scale difficult.

The logs were delivered to the mill pond and sawed without delay on a seven-foot head saw into 3/4-inch boards, which were ripped into 3- and 6-inch wide flooring strips. The strips were from 4 to 16 feet long, averaging about 8 feet. They were piled in 4-feet by 4-feet by 16-feet package units using 9 stickers per course. No narrow, dry stickers were available, and most of the stickers used were green Douglas fir and white fir, 1- by 4-inch by 4 feet in size. Some cull 3/4 by 3-inch flooring strips were cut to 4 feet in length and also used for stickers. Dry 1- by 2-inch stickers would have been preferable.

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[1] Torgeson, O. W., U. S. Forest Products Laboratory Report 1684, "Kiln-drying Schedules for 1-inch Laurel, Madrone, Tanoak, and Chinquapin".

Air-drying Test Procedure

The package units were moved to the air drying yard where they were piled three high on good pile foundations. The piles were spaced 12 to 18 inches apart. Each pile was covered to protect it from the sun. The sides were protected by the adjacent piles, but the ends of the piles were open. The piling was relatively open, except for the narrow space between piles, and fast drying could be expected.

Sixteen samples[2] were prepared and placed in the piles on the yard to determine the rate of air drying. These samples were weighed at intervals during the drying period and the moisture content determined. Weather reports were kept by the State Division of Forestry at a station only one-half mile from the yard; these reports have been used as a record of the drying conditions.

Air-drying results

The 3/4 by 3-inch and 3/4 by 6-inch strips dried rapidly (fig. 1). The average moisture content of the stock had reached 20 percent in one month. The wettest samples had dried to less than 20 percent in only 47 days, at which time all the stock could have been kiln dried readily with little danger of drying degrade.

This fast drying was accomplished with no drying defects, such as surface checking, end splitting, and honeycombing. Case-hardening stresses can not be classed as a drying defect because they develop during any normal drying process. These drying stresses can be relieved after both yard drying and kiln drying by subjecting the stock to humidity conditions that will permit a regain of moisture. Obviously, this can be done more readily in the kiln, where drying conditions can be controlled, than on the drying yard.

The small size of the flooring strips (3/4 x 3 in. and 3/4 x 6 in.) was an important factor in the fast drying without defects under the severe air drying conditions that prevailed. The results of this experiment do not permit the broad conclusion that all thicknesses of California black oak can be air dried readily without drying defects, but the results do show that 3/4-inch strips can be air dried successfully when piled properly on the yard. Furthermore, this experience with 3/4-inch stock indicates that full one-inch stock can be air dried successfully.

These results show a drying rate that can be duplicated only during the active drying season. Similar material handled in the same way, but piled during the wet, cold fall and winter season, would require considerably longer to dry. The danger from surface checking would also be much less during this slow drying season, which may be important in air drying thicker stock without defects.

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[2] U. S. Forest Products Laboratory Report 1607, "Use of Kiln Samples in Operating a Lumber Dry Kiln".

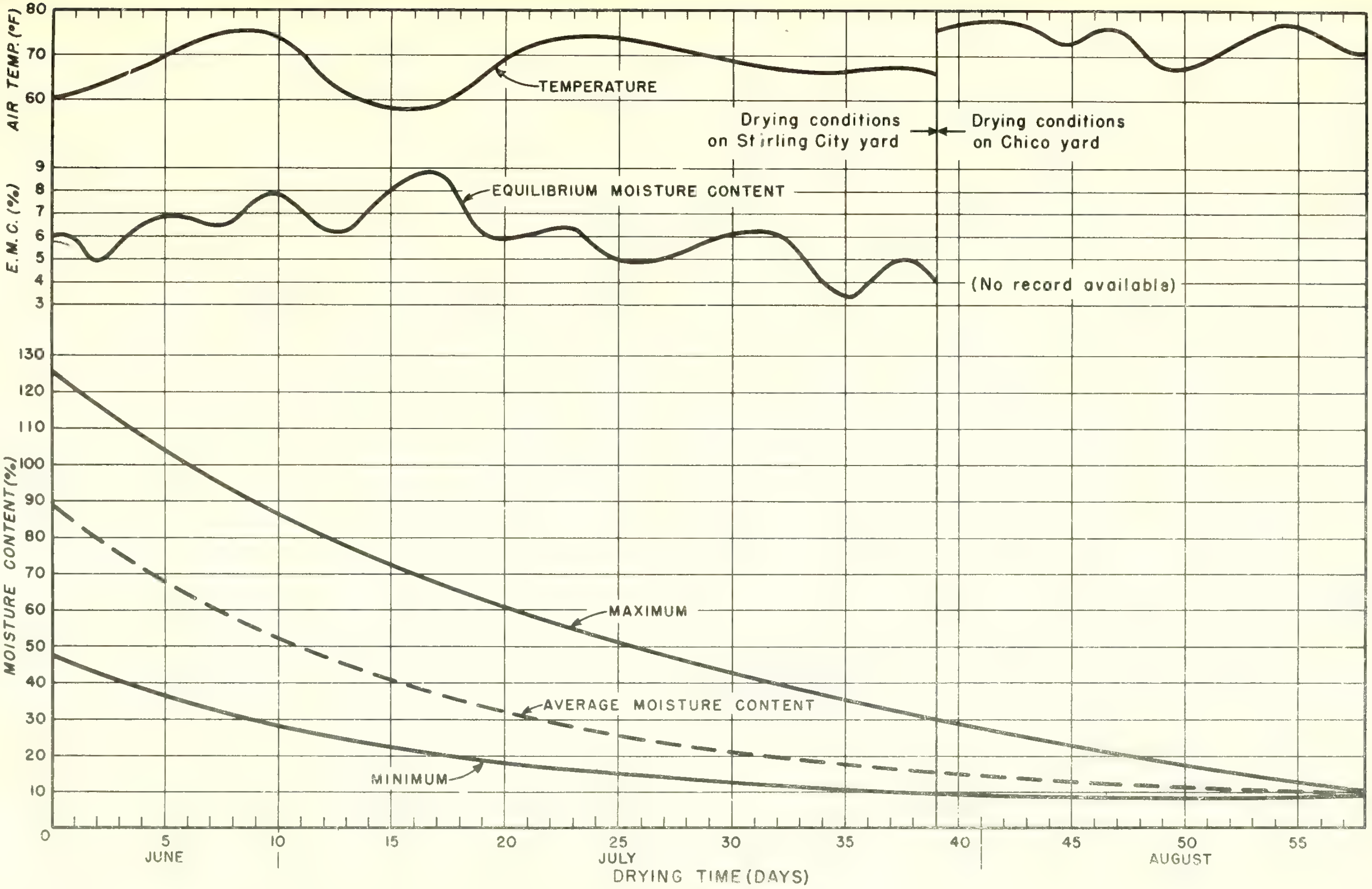

Figure 1.--Air drying conditions on the yard and the resultant drying rate of 3/4 by 3-inch and 3/4 by 6-inch California black oak flooring strips.

Kiln-drying Test Procedure

Four kiln runs were made in a small experimental dry kiln[3] and one in a large commercial kiln. Each charge in the small kiln contained 400 to 500 bd. ft. of 3/4-inch strips. Each load was 4 feet wide, 8 feet long and 4-1/2 to 5 feet high. At the time of the first experimental kiln run, this stock had been on the air drying yard four weeks and had dried to a moisture content of 26 percent. By the time of the fourth run it had further dried to 18 percent and at the time of drying in the commercial kiln had reached a moisture content of only 10 percent.

The drying conditions used in the first run in the experimental kiln were somewhat conservative (fig. 2). Because the results were encouraging, the dry bulb temperature during the next run was maintained at 180° F. This temperature is more severe than usually used. In run No. 4 (fig. 3) the initial dry bulb temperature of 140° F. was held until the average moisture content of the samples was 15 percent, then the temperature was raised to 180° F.

The relative humidity conditions during these experimental runs were controlled to maintain a rather low equilibrium moisture content[4]. The stock had already dried considerably during air drying and a moisture gradient was already established. The surface fibers were no longer in tension across the grain and there was no further danger from checking. Therefore the relative humidity in the kiln was lowered to 20 to 30 percent after only a few hours at 50 to 60 percent. These low relative humidity conditions were conducive to rapid drying and could be used safely since the danger from checking had passed.

The strips had air dried to such a low moisture content before being dried in the commercial kiln that there was no real kiln drying problem. The dry bulb temperature was held at 140° F. with a wet bulb depression of 40° over one night. The dry bulb temperature was then raised to 180° F., while maintaining a 40° F. wet bulb depression (wet bulb temperatures raised from 100° F. to 140° F.). After 24 hours of drying the stock was equalized for 16 hours at an 8.0 percent equilibrium moisture content (160° F. dry bulb and 140° F. wet bulb). The stock was conditioned for two hours at 160° F. dry bulb temperature and 152° F. wet bulb temperature to relieve drying stresses. The total time in the kiln was only 42 hours and could have been reduced by several hours had it been necessary to do so.

Kiln-drying Results

The results obtained from the four runs in the small experimental kiln and one run in the commercial kiln indicate that air dried California black oak can be kiln dried as readily as eastern red oak.

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[3] Torgeson, O. W., U. S. Forest Products Laboratory, Report 1671, "Small Demountable-type Lumber Dry Kiln for Experimental Drying".

[4] Smith, H. H., U. S. Forest Products Laboratory Report 1651, "Relative Humidity and Equilibrium Moisture Content Graphs and Tables for Use in Kiln Drying Lumber".

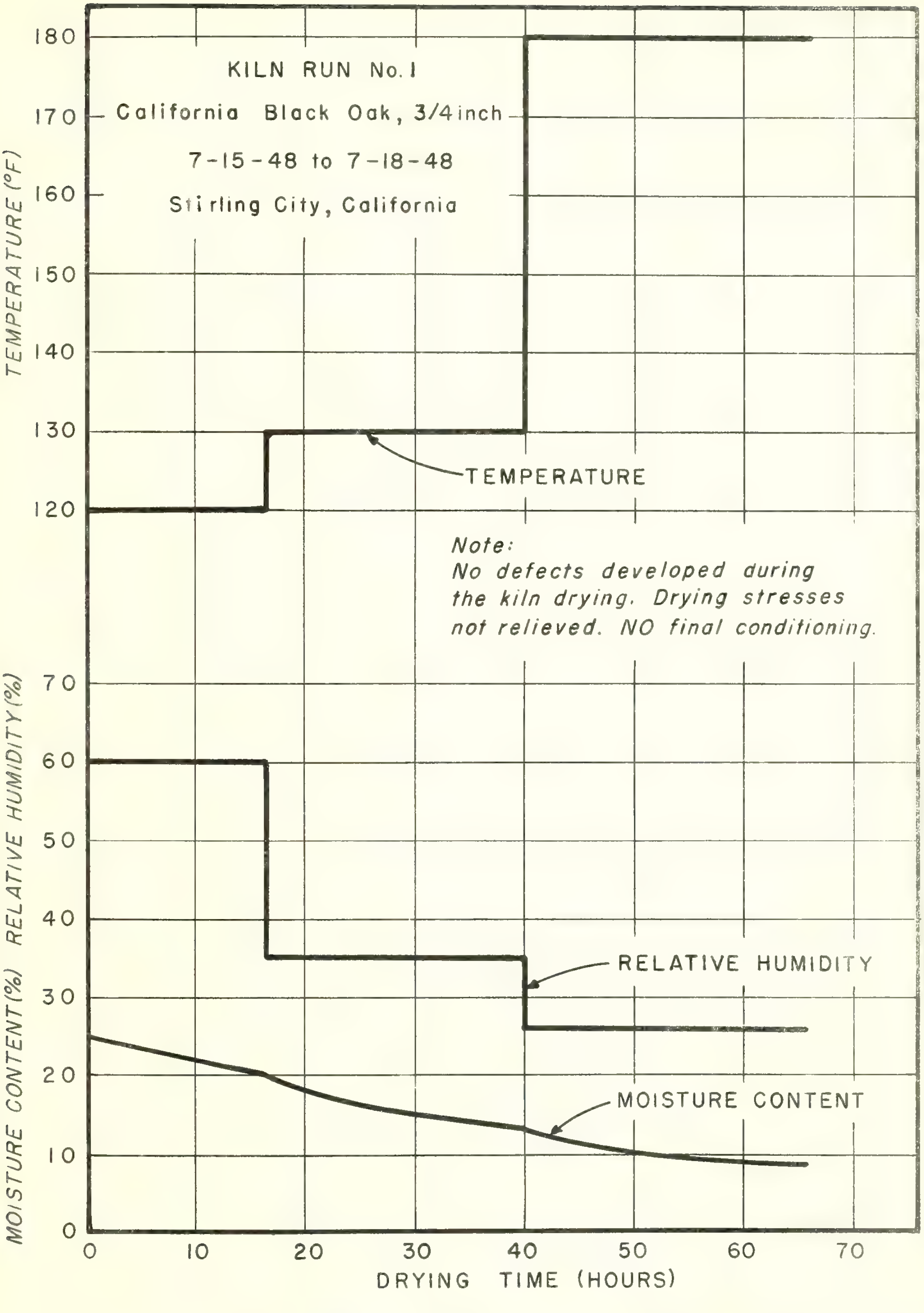

Figure 2.- Test run of 3/4-inch California black oak flooring strips in experimental kiln using moderate drying schedule.

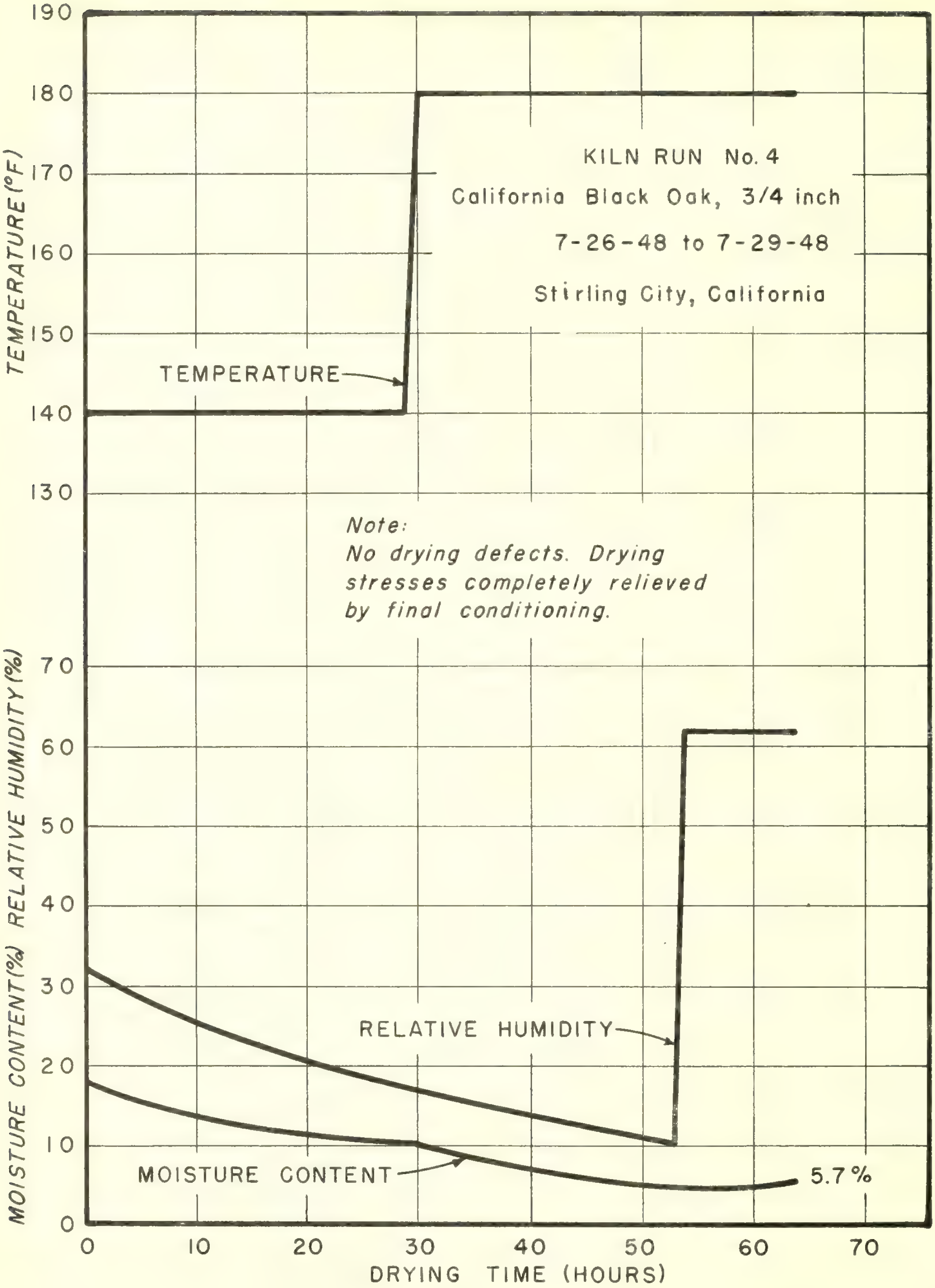

Figure 3.- Test run of 3/4-inch California black oak flooring strips in experimental kiln using accelerated drying schedule with final conditioning.

Figures 2 and 3 show the drying conditions in two of the experimental runs. The drying time was 66 and 64 hours, respectively. The drying conditions in the second were more severe and the total drying time of 64 hours includes a 10-hour conditioning treatment to relieve the drying stresses.

Drying defects occurred in only the second experimental kiln run, in which the initial temperature was 180° F. In this run severe honeycomb developed in some areas of the stock that had been covered by the wide, green stickers used during air drying. Wood in these areas had been covered during air drying and had not been subject to the same drying conditions as the wood between the stickers. It had not dried to a sufficiently low moisture content to withstand the high kiln temperatures without serious defects.

The development of honeycomb in wet areas of this oak, but not in adjacent drier areas, substantiates the theory that wood that has been dried below the fiber saturation point[5/], and thus contains no free water, can be kiln dried at high temperatures without danger from drying defects.

Conclusions

The results of these experiments indicate that California black oak cut into thin sizes, can be dried in a relatively short time without drying defects.

Three-quarter inch stock can be air dried in only 6 weeks during the active drying season, but may require at least twice that long a time during the wet, winter weather. The method of piling will affect the rate of drying and the extent of warping during air drying. If it is found that 4/4 or thicker stock checks when piled for air drying by the method used in this experiment, modifications of the piling can be made to slow the rate of drying and thus reduce the occurrence of drying defects[6/].

The kiln drying of previously air dried 3/4-inch stock is relatively easy and can be accomplished in a modern forced-circulation fan kiln in less than 3 days without drying defects. A schedule using 140° F. dry bulb temperature until the moisture content reaches 15 percent and then a final temperature of 180° F. can be recommended. The initial relative humidity should be about 50 percent, but can be lowered to the desired minimum by the end of the second day.

[5/] Stamm, A. J., U. S. Forest Products Laboratory Report 859, "The Fiber-saturation Point of Wood as Obtained from Electrical Conductivity Measurements".

[6/] Espenas, L. D., U. S. Forest Products Laboratory Report 1657, "Air Seasoning of Lumber".

The following kiln schedule is suggested for air dried 3/4 flooring strips up to 6 inches in width:

Moisture Content at which change is to be made, percent	Dry Bulb	Wet Bulb	Relative Humidity	Equilibrium Moisture Content
	°F.	°F.	pct.	pct.
25	140	120	54	8.0
20	140	100	25	4.1
15 to Final	180	130	26	3.3
Equalizing (8 to 12 hrs. for final MC of 6% to 8%)	180	150	47	5.7
Conditioning (2 to 4 hrs. for final MC of 6% to 8%)	180	168	75	10.1

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
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[illegible] Director

No. 64

November 1949

AN INDEX OF RIPENESS FOR SUGAR PINE SEED[1]

By

H. A. Fowells, Silviculturist

Immature or unripe seed may be one cause of the poor germination of sugar pine occasionally experienced in nursery practice or direct seeding projects. Ripeness of pine seed, or the time to harvest cones, is usually judged by a change from green to brown in the color of cones or by the development of a firm consistency in the endosperm. However accurately these criteria may be applied, they are subjective and cannot be described well enough to permit consistency in their use. More objective criteria have been proposed by Wakeley (2) and Maki (1). Wakeley suggested in 1938 that cones of the southern pines not be collected until they floated in water. Recently he has proposed floating in oil of specific gravity 0.88 as an index of ripeness (personal communication). Maki found that the germination of ponderosa pine seed was acceptable when the cones had a specific gravity of 0.86. This paper describes an index of ripeness for sugar pine seed.

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[1] This study was conducted at Stanislaus Experimental Forest under the direction of Duncan Dunning, in charge of Forest Management Research.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Methods

For the study, six sugar pine trees bearing abundant cones were selected in 1941. The trees were on north- and south-facing slopes, giving a range of environmental conditions which might affect ripening. Ten cones or more were picked from each tree on each of three sampling dates. The cones picked from any tree were selected throughout the length of the crown. Because of poor germination of seed from all the collections, another series of cones was picked in 1948, the first heavy seed crop year after 1941. On the collection dates the weight in grams and the volume in cubic centimeters (by displacement in water) were determined for ten undamaged cones from each tree.

Seed was extracted from the 1941 cones by air drying. Facilities for drying were inadequate, and some or all of the cones may have dried too slowly to yield good seed. Seed of the 1948 collection was removed from the cones by dissection within a day after collection and was immediately air dried. In each year the seed was stored for approximately two months at 41° F. and was then stratified at 41° F. for slightly more than two months. Samples for germination tests consisted of 50 seeds from each of five cones selected at random from the ten used for specific gravity determinations.

Results

Specific gravity of the cones

The specific gravity of the cones decreased from one period to another in the two years. The average specific gravities of the cones in 1941 and in 1948 are tabulated below by collection dates. A difference of 0.02 between the average specific gravities of collection dates was significant in both sets of data.

1941		1948	
August 28	0.88	September 9	0.92
September 9	0.87	September 24.	0.87
September 29.	0.81	October 7	0.78

The differences between means of trees for sampling dates were statistically significant. This variability makes it necessary to sample cones of each tree for which the average specific gravity is desired.

Germination of seed

The germination percent increased significantly from the first collecting date to the second and from the second to the third. In the 1941 tests germination was unaccountably low for the three collections, being only 1.4 percent for the first, 3.9 percent for the second, and 4.8 percent for the last. However, the proportion of seed having developed embryo and endosperm, as indicated by cutting tests, was 78 percent, 82 percent and 85 percent for the first, second and third collections respectively.

In 1948 the average germination by periods was 23 percent, 38 percent, and 88 percent (fig. 1). The forms of the germination curves suggest that delayed germination, which is occasionally experienced with immature seed, did not occur in the early collections. Either the period of stratification was long enough to avoid delay or the sample contained a small proportion of mature seed which germinated and a large proportion of immature seed which did not.

Relation between specific gravity and germination

The extent of relation between specific gravity of cones and seed germination in 1948 (fig. 2) is evident from the correlation coefficient of -0.75. Specific gravity alone explains 56 percent of the variation in the germination of the seeds. The relation of specific gravity to germination is shown also by covariance analysis. Thus the germination percents for the three collection dates would not have differed significantly if specific gravity had no effect on germination. In view of the many possible causes of variability in germination, a single-factor relationship this large is certainly important.

Change in weight of seed

The air-dry weight of the 1948 seed increased appreciably from one date to the next. The average weight of 50 air-dry seed was 9.40 grams in the first collection, 10.80 grams in the second, and 11.41 grams in the last. This increase in weight suggests at least that seed was not completely developed in the early collections.

Color of cones

Color of the cones before they opened naturally did not consistently indicate maturity of the seed. In the first 1948 collection, seed of the poorest germination came from cones which were brownest in color. Highest germination came from cones which had scarcely a tint of brown. In the last collection, seed of which germinated at the rate of 88 percent, cone color varied from greenish brown to brown.

Application in Cone Collection

The strong relation between specific gravity of the cone and germination of the seed offers an objective method of accepting or rejecting the cones on a particular tree. If, for example, 85 percent germination is desired, then cones should not be picked until the average specific gravity of the cones on a tree is 0.80. How to detect the average specific gravity of cones on a given tree with a reasonable certainty and with minimum equipment is obviously a sampling problem.

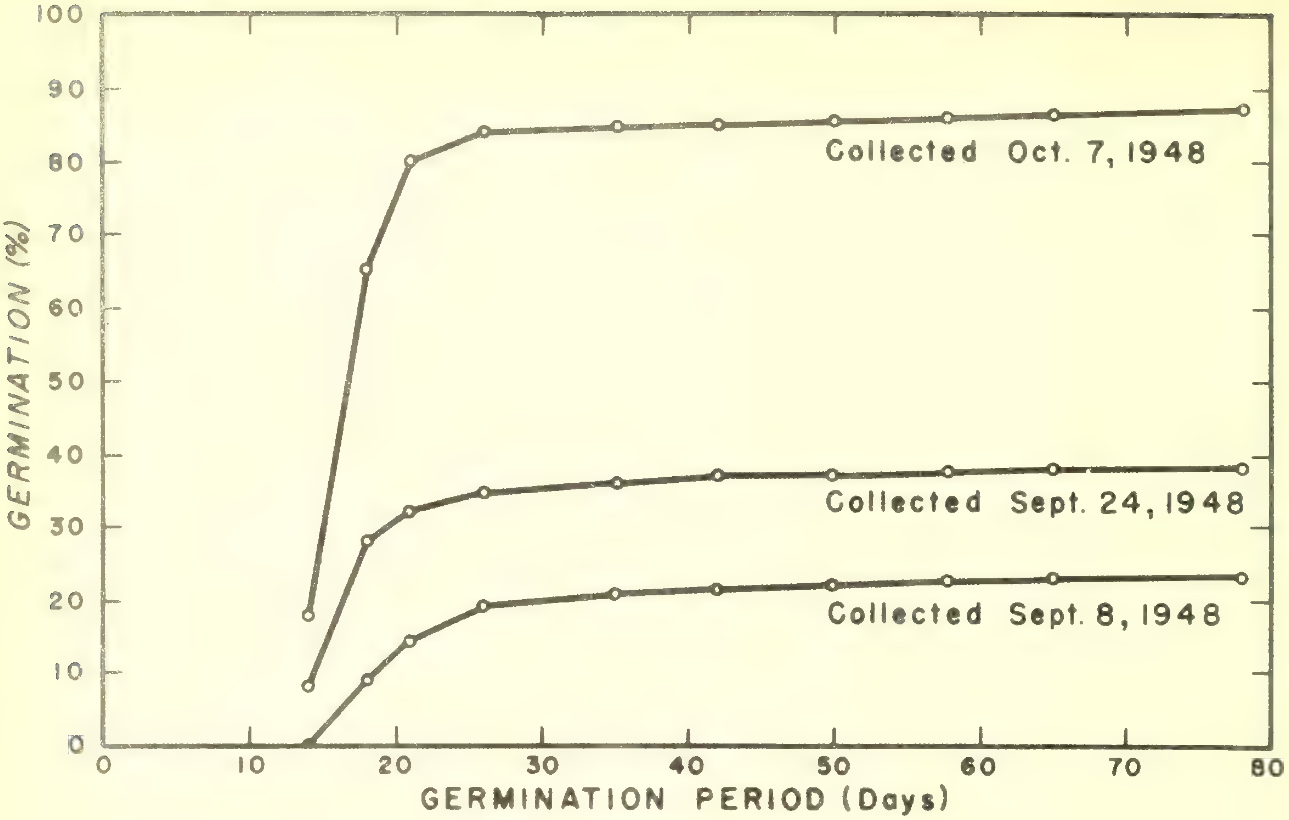

Figure 1. – Germination of seed.

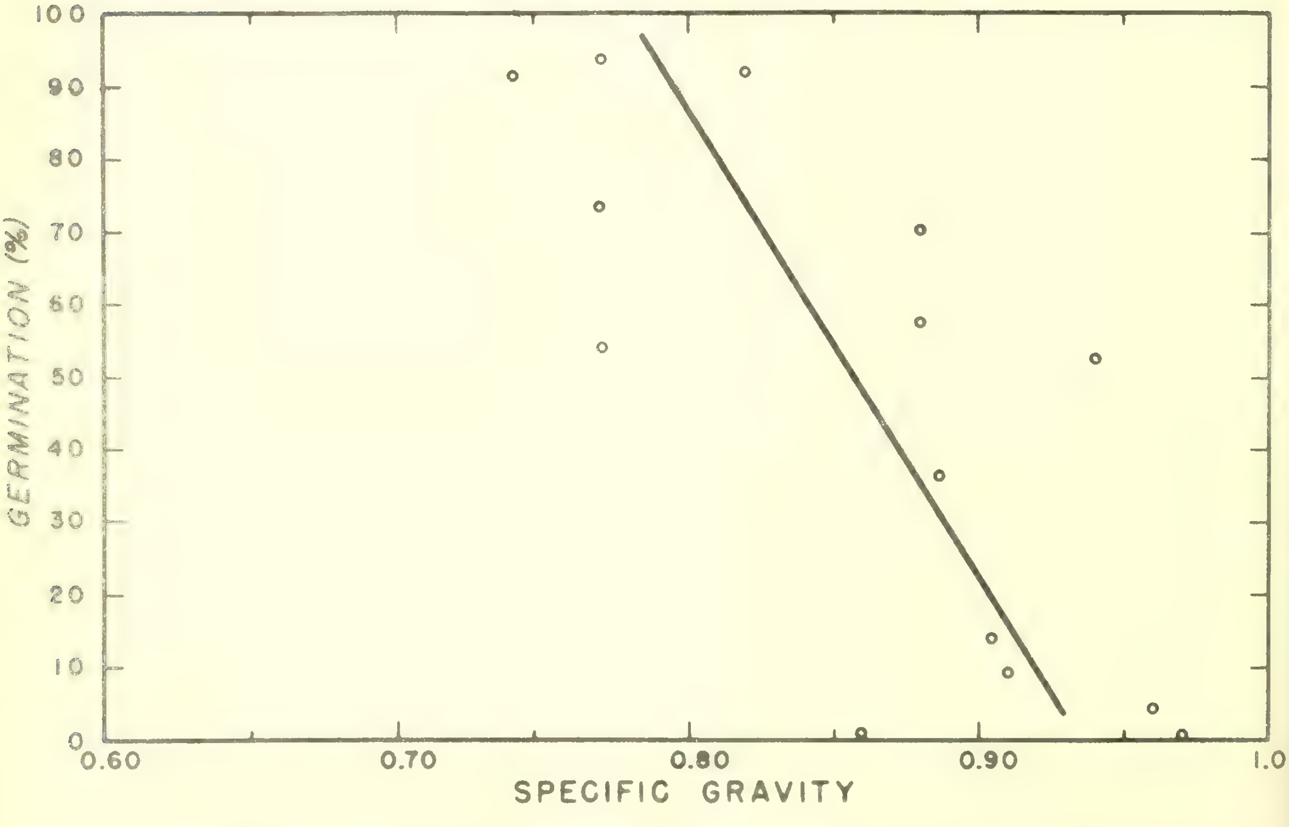

Figure 2.– Relation between specific gravity of the cone and germination of the seed, 1948.

A simple procedure might be based on the probability that cones would float or sink in some liquid, such as common kerosene, which has a specific gravity of 0.80 in the range 60° to 80° F. It is possible to compute how many cones from a population of assumed mean would float in kerosene. The probability is 0.50 that 3 or more cones of a sample of 5 will float when the mean specific gravity of cones in a tree is 0.80. Occasionally three or more cones will float when the mean is 0.81 (probability of occurrence is 0.20), and rarely when the mean is 0.82 (probability of occurrence is 0.04). If only 2 cones float, there is the possibility that the mean of the tree is as high as 0.84. The expected germination related to this average specific gravity is only 60 percent. To be reasonably sure of at least 80 percent germination, 3 or more cones of a sample of 5 should float.

Because of the variability between trees, each tree must be sampled to determine whether the specific gravity of the cones is low enough to give the desired germination percent.

There are some practical limitations in the use of such a procedure. The test applies only to freshly picked cones. It is therefore necessary to sample cones from the tree or to be sure that cones on the ground, as in a logging area, have lain there no more than a day or two. Obviously aborted cones or insect-riddled cones will not yield good seed even though their specific gravity is low, that is, many of them float in kerosene.

Proper cone collection, of course, must be accompanied by good seed extraction practice to avoid germination failure, such as that occurring in the 1941 seed.

Because sugar pine cones may be 20 inches long and 5 inches in diameter, a large container is needed for the floating test. The outside can of a standard rain gage is satisfactory; however, some method of catching the overflow is desirable to avoid carrying a large supply of kerosene. The small drums used for tractor lubricants might be satisfactory containers. Probably a better container could be fabricated from sheet metal to form a tank roughly 8 x 8 x 24 inches, in which cones could be placed horizontally.

In view of the costs of seed collection and the necessity to make the most of infrequent seed crops, an objective system of determining ripeness, such as this specific gravity index, appears worthwhile.

References

(1) Maki, T. E. 1940. Significance and applicability of seed maturity indices for ponderosa pine. Jour. Forestry 38: 55-60.

(2) Wakeley, P. B. 1938. Harvesting and selling seed of southern pines. U. S. Dept. Agr. Leaflet 156.

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 65 December 8, 1949

ESTIMATED LUMBER PRODUCTION IN CALIFORNIA - 1948[1]

By George F. Burks
Forest Survey, Division of Forest Economics

Lumber production in California in 1948, for the third successive year exceeded all previous records. The estimated cut was 3,962,910,000 board feet. This cut when combined with the production of all other forest products exceeds four billion board feet.

This estimate of lumber production was compiled by the California Forest and Range Experiment Station from data collected in a three-way cooperative canvass of California sawmills by the West Coast Lumbermen's Association, the Western Pine Association, and the Experiment Station. Western Pine Association covered production of mills in the Pine Region, while the West Coast Lumbermen's Association and the Experiment Station canvassed sawmills in Del Norte and Humboldt Counties. In addition, the Experiment Station sampled the remainder of the counties in the Redwood Region and worked closely with the two Associations in checking the accuracy and completeness of their mailing lists of active sawmills.

The reliability of the total lumber production figure is indicated somewhat by the fact that 3,629,767 M bd ft., or about 92 percent of total production, was included in the reports of the 529 responding mills. The remaining 8 percent of total production is attributed to the 442 nonrespondent and nonsampled active sawmills, largely in the smaller size classes. This amount was estimated by expanding the production of the sampled mills in each size class by the ratio of mills sampled to the total number of mills in each production size class.

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[1] Richard H. May and Alexander Simontacchi collected the production data for the Experiment Station and compiled the statistics appearing in this report.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Highlights of 1948 Lumber Production

Total production in 1948 showed an increase of 16 percent over 1947. The segregation of the 1948 production by species compared with that of 1947 is presented in Table 1. In both years the relative production by species remained essentially the same, with ponderosa pine, Douglas-fir and redwood accounting for about 80 percent of the total.

The production for 1948 continues a trend that has been generally upward for the past 10 years (fig. 1). The change was less noticeable during the war years of 1941-44 inclusive, but for the period 1945 through 1948 there has been a striking increase each year.

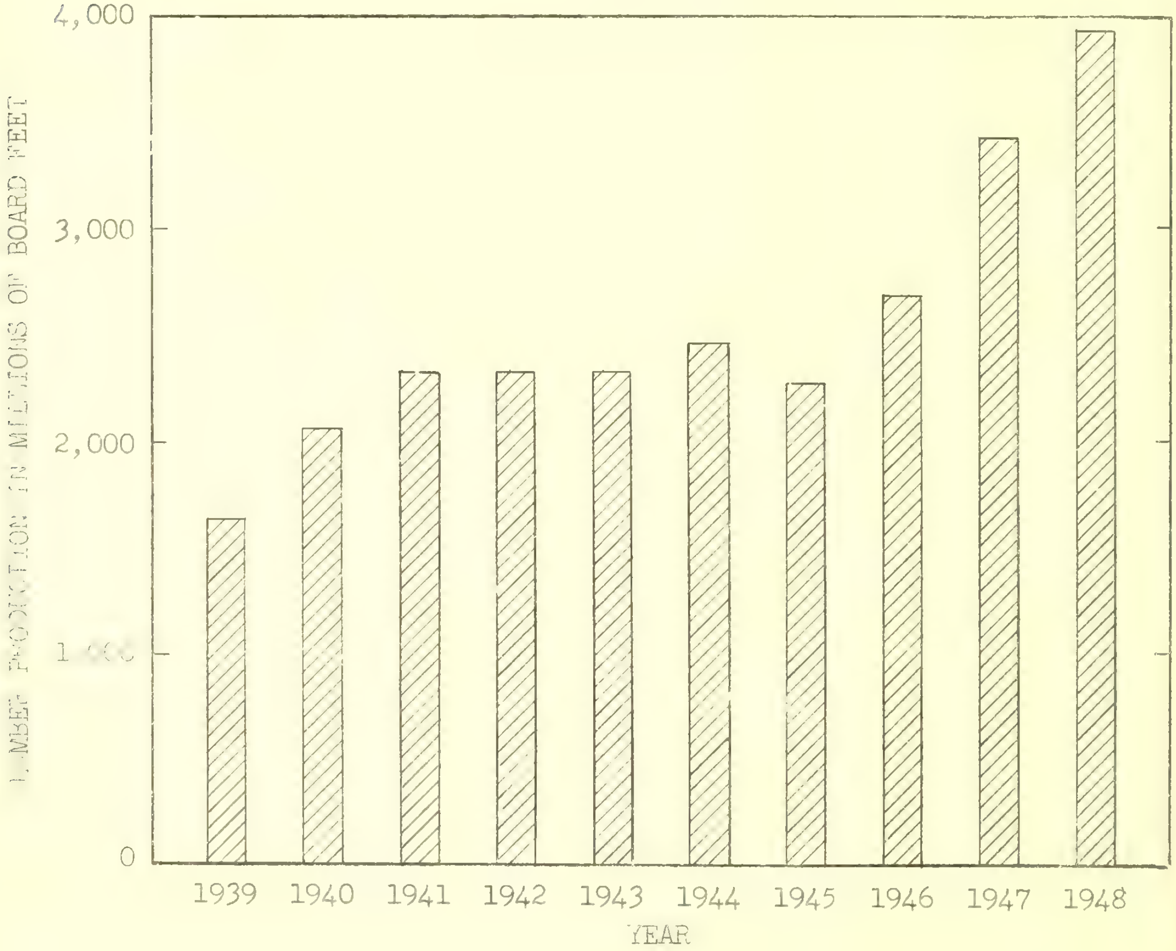

Figure 1.- Lumber production in California, 1939-1948.

Pine Region

Lumber production estimates by species and production size class for the Pine Region in 1948 are presented in Table 2. The 2.6 billion board feet of lumber produced in 1948 was about 8 percent higher than the 2.4 billion board feet produced in 1947. Approximately the same number of mills were active in both years.

Ponderosa and sugar pine account for about two-thirds of the 1948 Pine Region total, while Douglas-fir and the true firs account for most of the remainder.

Of the total estimated cut of 2,607,690 M bd. ft., 2,440,318 M bd. ft. or 94 percent, was actually reported by slightly more than one-half of all active sawmills. Therefore, only 6 percent of the Pine Region production is estimated.

Redwood Region

Lumber production estimates by species and production size class for the Redwood Region in 1948 are presented in Table 3. The 1.3 billion board feet of lumber produced in 1948 was about 31 percent higher than the 1.0 billion board feet produced in 1947. The number of active sawmills has increased proportionately with 393 on record for 1948.

Redwood and Douglas-fir made up approximately 98 percent of the entire cut of the region.

As in the Pine Region, the largest portion (1,189,449 M bd. ft.), or 88 percent of total regional production (1,355,220 M bd. ft.), was actually reported by one-half of all active mills. Thus, only 12 percent of Redwood Region production is estimated.

County Statistics

Coincident with the regional compilations, estimates of production were made for all timber producing counties. But these amounts are not reported here because the basic data did not permit equally sound estimates for all counties. However, it was apparent that Humboldt County was again the leading producer by a wide margin. Other leading counties, all cutting more than 200 million feet, were Mendocino, Siskiyou, Plumas, Lassen, Shasta, and possibly El Dorado.

In spite of the limitations of the county estimates, some individuals, organizations, or concerns may desire the information. It may be obtained upon request from the Experiment Station.

Table 1.- Production of lumber by species
California, 1947 and 1948

Species	Lumber production				Change from 1947 to 1948
	1948		1/1947		
	M bd. ft.	Percent	M bd. ft.	Percent	Percent
Ponderosa pine2/	1,458,120	36.8	1,322,182	38.8	+ 10.3
Douglas-fir	925,440	23.4	768,866	22.6	+ 20.4
Redwood3/	793,250	20.0	529,921	15.5	+ 49.7
White fir and red fir	471,100	11.9	417,627	12.2	+ 12.8
Sugar pine	236,930	6.0	281,406	8.2	- 15.8
Incense cedar	68,960	1.7	70,354	2.1	- 2.0
Sitka spruce	7,480	0.2	12,315	0.4	- 39.3
Port Orford cedar	680	—	643	0.1	—
Western white pine	510	—	None reported		—
Alder4/	200	—	742		—
Western hemlock	160	—	242		—
Lodgepole pine	80	—	172		—
Monterey pine	—	—	4,052	0.1	—
All species	3,962,910	100.0	3,408,522	100.0	+ 16.3

1/ From Census of Manufactures, 1947, Lumber and Timber Basic Products, U. S. Department of Commerce, Washington, D. C., 1949.

2/ Includes small volume of Monterey pine in 1948.

3/ Includes 130 M bd. ft. of bigtree in 1948.

4/ Includes 62M bd ft. of oak in 1947.

Table 2.- Estimated lumber production - by species and production size class California Pine Region[1] - 1948

Production size class	Total no. of active mills	No. of mills reporting	Lumber sawed by species (M bd. ft.)[2] Ponderosa pine[3]	Sugar pine	Douglas-fir	White fir and red fir	Incense cedar & other softwoods[4]	All species[6] Quantity	All species[6] Percent
8 (50MM and over)	7	7	361,860	58,710	22,060	103,480	9,290	555,400	21.3
7 (25 to 49.9MM)	21	21	289,260	75,090	93,110	145,370	14,320	617,150	23.7
6 (15 to 24.9MM)	20	20	174,700	42,890	57,220	68,430	9,290	352,530	13.5
5 (10 to 14.9MM)	19	19	108,860	5,630	42,030	49,370	2,730	208,620	8.0
4 (5 to 9.9MM)	66	64	243,970	31,130	106,430	45,780	17,450	444,760	17.1
3 (1 to 4.9MM)	136	98	212,050	16,050	59,400	32,810	11,710	332,020	12.7
2 (500 to 999M)	97	29	36,450	4,270	11,850	6,360	3,620	62,550	2.4
1 (50 to 499M)	167	55	25,090	1,380	2,880	3,090	1,240	33,680	1.3
0 (under 50M)	45	21	750	150	50	0	30	980	-
All classes									
Amount	[5]578	334	1,452,990	235,300	395,030	454,690	69,680	2,607,690	
Percent	100.0	58.0	55.7	9.0	15.2	17.4	2.7		100.0

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[1] Includes all counties in California not listed in the Redwood Region. (See Table 3, footnote 1.)

[2] Shown to nearest 10 M bd. ft.

[3] Includes Jeffrey pine and Coulter pine.

[4] In addition to incense cedar, includes 510 M ft. western white pine; 130 M ft. bigtree; and 80 M ft. lodgepole pine.

[5] In addition there were 92 nonoperating mills in the Pine Region in 1948.

[6] Probably some hardwood lumber was cut, as in former years, but none was reported.

Table 3.- Estimated lumber production - by species and production size class California Redwood Region[1] - 1948

Production size class	Total no. of active mills	No. of mills reporting	Lumber sawed by species (M bd. ft.)[2]									
			Redwood	Douglas-fir	White fir[3]	Sitka spruce	Ponderosa pine[4]	Sugar pine	Port Orford cedar	Alder	All species Quantity	All species Percent
8 (50MM and over)	5	5	248,200	35,490	13,240	-	-	-	-	-	296,930	21.9
7 (25 to 49.9MM)	7	7	97,770	120,900	2,290	1,170	-	30	-	-	222,160	16.4
6 (15 to 24.9MM)	3	3	48,900	9,470	60	-	-	-	-	-	58,430	4.3
5 (10 to 14.9MM)	13	13	79,380	86,050	270	-	840	560	-	-	167,100	12.3
4 (5 to 9.9MM)	32	32	98,490	128,320	560	-	1,020	300	620	-	229,310	16.9
3 (1 to 4.9MM)	116	77	193,170	97,520	150	5,710	1,840	240	60	200	298,890	22.1
2 (500 to 999M)	77	15	16,300	36,740	-	200	-	-	-	-	53,240	4.0
1 (50 to 499M)	122	38	10,620	15,870	-	400	1,430	500	-	-	28,820	2.1
0 (under 50M)	18	5	290	50	-	-	-	-	-	-	340	-
All classes												
Amount	[5]393	195	793,120	530,410	16,570	7,480	5,130	1,630	680	200	1,355,220	
Percent	100.0	50.0	58.6	39.1	1.2	0.6	0.4	0.1	-	-		100.0

---

[1] Includes following counties: Del Norte, Humboldt, Mendocino (excepting extreme eastern portion), Sonoma, Marin, Alameda, Santa Clara, San Mateo and Santa Cruz.

[2] Shown to nearest 10 M bd. ft.

[3] Includes 160 M bd. ft. of Western hemlock by class 4 mills.

[4] Includes a small amount of Monterey pine.

[5] In addition there were 45 nonoperating mills in the Redwood Region in 1948.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director

No. 66 February 6, 1950

BOARD-FOOT AND CUBIC-FOOT VOLUME TABLES FOR SECOND-GROWTH REDWOOD

By A. A. Hasel[1]
Forest Survey, Division of Forest Economics

The tables presented here are for use in estimating the volume of second-growth redwood trees: board-foot volume by the Scribner and International 1/4" rules, cubic volume in the sawlog portion, and cubic volume to a 4" top diameter. The tables were prepared in connection with the forest survey of California, which is being conducted as part of the nation-wide Forest Survey Project.

Since the tables by Bruce and Schumacher[2] were prepared, sufficient time has elapsed to provide larger trees for measurement. The volumes given here for sawlog-size trees are based on measurements on 118 trees, of which 70 represent new data mainly in the larger size classes. The largest tree measured was 60 inches d.b.h., and the tables extend through this diameter class. For second-growth trees larger than 60 inches d.b.h. it is likely that existing old-growth tables will apply satisfactorily. Data for trees of less than sawlog size were randomly selected from Forest Service data collected in 1899. All data were collected in Del Norte, Humboldt, Mendocino, and Sonoma Counties. The top utilization for the sawlog portion of the trees was determined from a survey of utilization practices on Forest Service sales (fig. 3) in other timber types, since an adequate sample of practice in second-growth redwood was not available.

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[1] Grateful acknowledgment is made of assistance given by other members of the Division of Forest Economics, including Miss A. E. Rae for computations, K. Schoenlank for compilation of volumes, and E. M. Hornibrook for helpful advice.

[2] 1925. Bruce, Donald, and Francis X. Schumacher. Revised Volume Tables for Second-growth Redwood. Jour. Forestry 23: 148-155.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA

Procedure

Tree measurements were plotted on Forest Service Tree Measurement Form 558a (Rev. November 1928) and cubic volumes were obtained by planimetering. Board-foot volumes were obtained by scaling in 16-foot lengths, allowing 0.3-foot for trim. Additional top sections and small trees were scaled as 8-foot logs or fractions of 8-foot logs. Diameters at the small end were read to 0.1-inch on Form 558a, and the scale was determined from the following formulas:

16-foot logs

Scribner volume = $0.79\ D^2 - 2D - 4$
International 1/4" volume = $0.796\ D^2 - 1.375D - 1.230$

8-foot logs

Scribner volume = $0.395\ D^2 - D - 2$
International 1/4" volume = $(0.44\ D^2 - 1.2D - 0.3)\ 0.904762$

The volume tables are based on the relationship of volume to diameter, height, and the Girard form class, which may be defined as d.i.b. at the small end of the butt 16-foot log expressed as a percentage of d.b.h. o.b.

Converting Factors

The volumes are tabulated for Form Class 70, which is average for the data, but factors are given for converting volumes to other form classes. The tables can therefore be readily adapted or localized to particular stands, or types of trees in the stand, by determining the form class of the particular stand to be cruised. Determination of form class on 50 trees, well distributed throughout the range of diameters and over the area, should be satisfactory for this purpose. If form class does not vary with diameter, the stand average may be used.

Heights to tip and to 4-, 8-, 10-, and 12-inch i.b. top diameters are curved over d.b.h. in Figure 1. These curves indicate average taper in the tops and therefore provide a guide to converting heights from one top diameter basis to another. Together with the curve of merchantable length in Figure 2, they make it possible to adjust the total cubic table to larger top diameters, or to approximate the board-foot volumes on a fixed top diameter basis.

Growth and Form-class Determinations

The bark thickness curves in Figures 4, 5, and 6 are useful in connection with growth studies and form-class determination.

Example of growth determination:

(1) Tree 30.0 in. d.b.h., 5 logs, present volume 1000 b.f. Scribner. Increment core shows 1.5" radial growth past 10 years.

(2) Fig. 4 indicates bark thickness now 4.8". Then, 30.0 - 4.8 - 2(1.5) ≐ 22.2 in. d.i.b. ten years ago.

(3) Fig. 6 indicates bark thickness of 4.2 in. 10 years ago, so 22.2 + 4.2 = 26.4 in. d.b.h. 10 years ago.

(4) Assume curve of height-diameter relationship indicates height of 4 logs to merchantable top for tree 26.4 in. d.b.h. From Table 1, volume 10 years ago is 615 + (710-615) 1/5 = 634 b.f.

(5) Growth during past 10 years was 1000 - 634 = 366 board feet.

Example of form class determination:

(1) D.B.H. of tree is 30.0 in. o.b.

(2) Determine location of top of first 16-foot log (1.5' stump on uphill side plus 16.0' log plus 0.3' trim): 17.8 ft. above ground.

(3) Carefully estimate average taper from b.h. to top of first log by use of plumb bob. Best to do this from uphill side of tree so that eye is about level with point midway between b.h. and top of log. Average one-side taper estimated to be 3.0 in.

(4) Then, 30.0 - 2(3.0) = 24.0 in. o.b. top first log. From Fig. 5, bark thickness is 3.0 in.

$$\frac{24.0 - 3.0}{30.0} \times 100 = 70 = \text{form class.}$$

The curve of form class over d.b.h., for all the data used is shown in Fig. 7. The average of all trees was very close to 70.

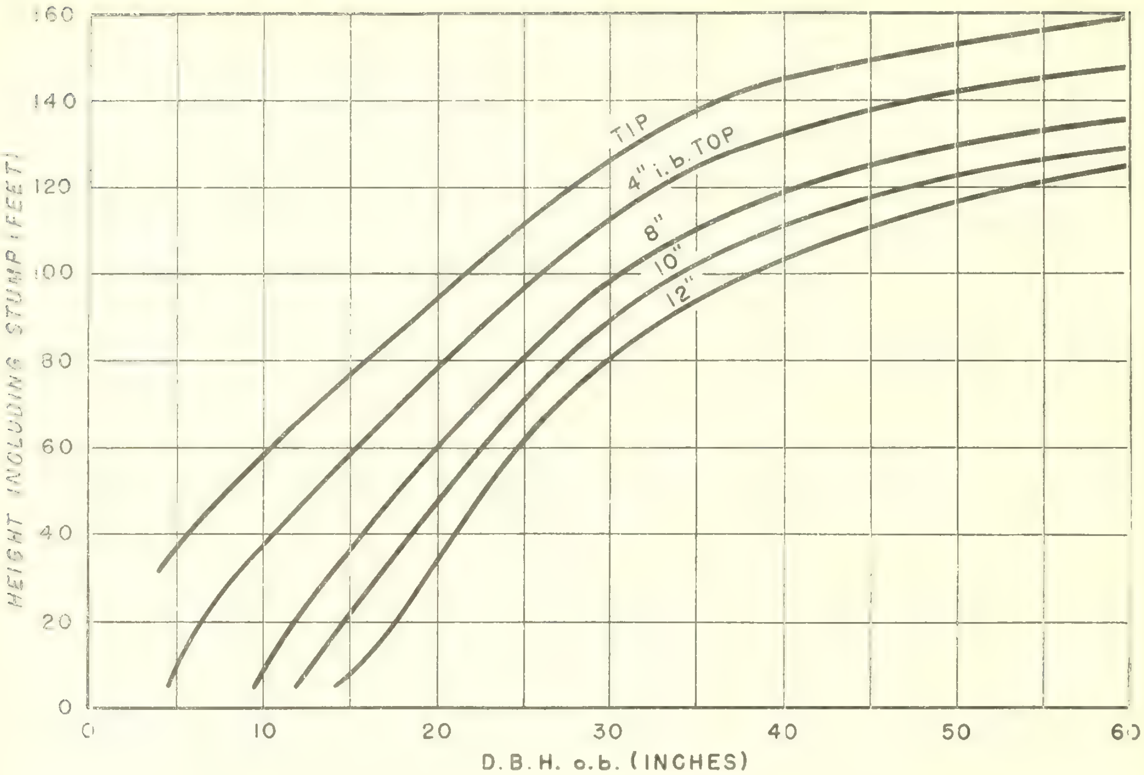

Fig. 1 — Height to tip and to fixed top of 4, 8, 10, and 12 inches, by d.b.h. Based on 145 trees used in preparing the volume tables.

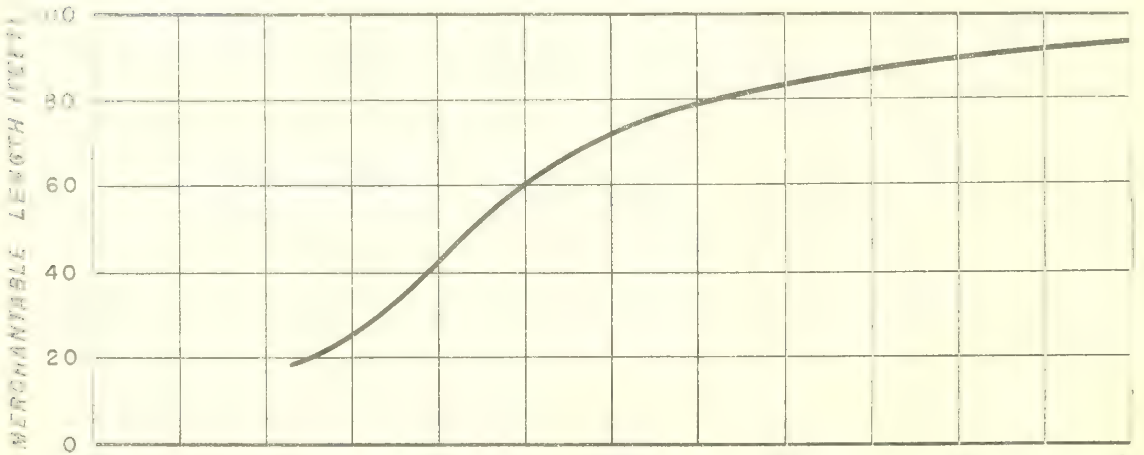

Fig. 2 — Merchantable length by d.b.h. Based on 118 trees use in preparing the volume tables.

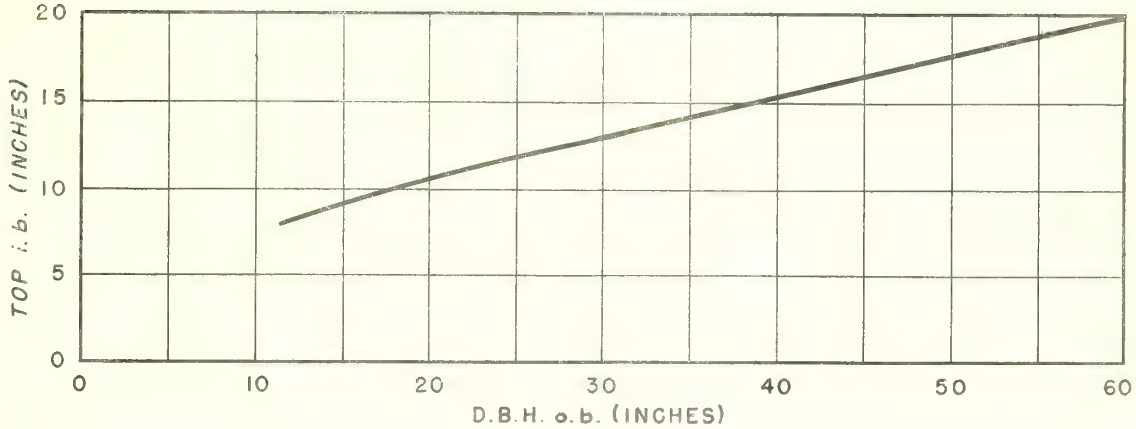

Fig. 3 — Top utilization by d.b.h. classes. (Based on Forest Service data for other species, 1945)

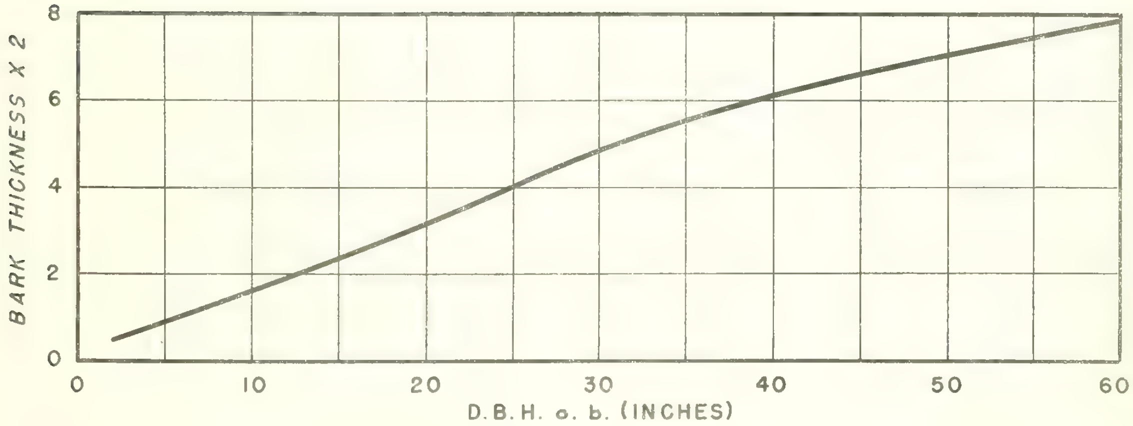

Fig. 4 — Double bark thickness in inches at B.H. by d.b.h. outside bark. (Based on 149 trees)

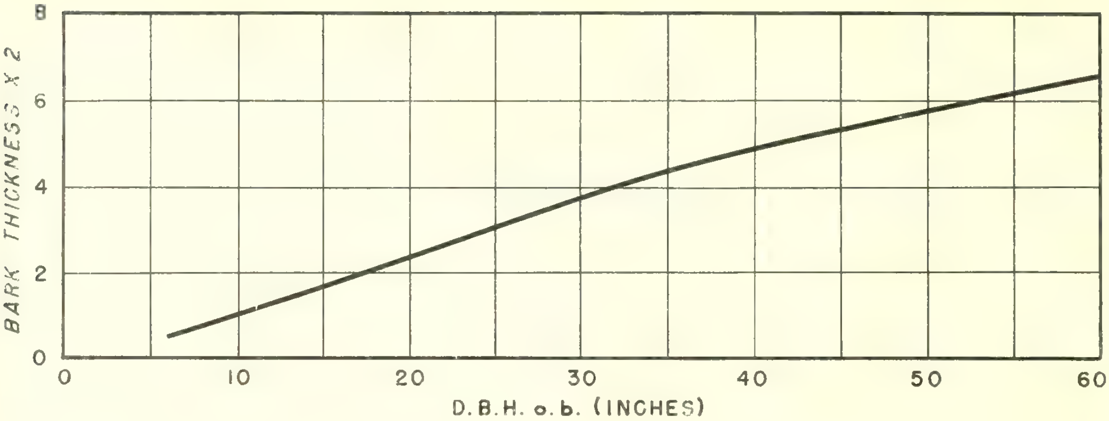

Fig. 5 — Double bark thickness in inches at top of first 16-foot log by d.b.h. (Based on 149 trees)

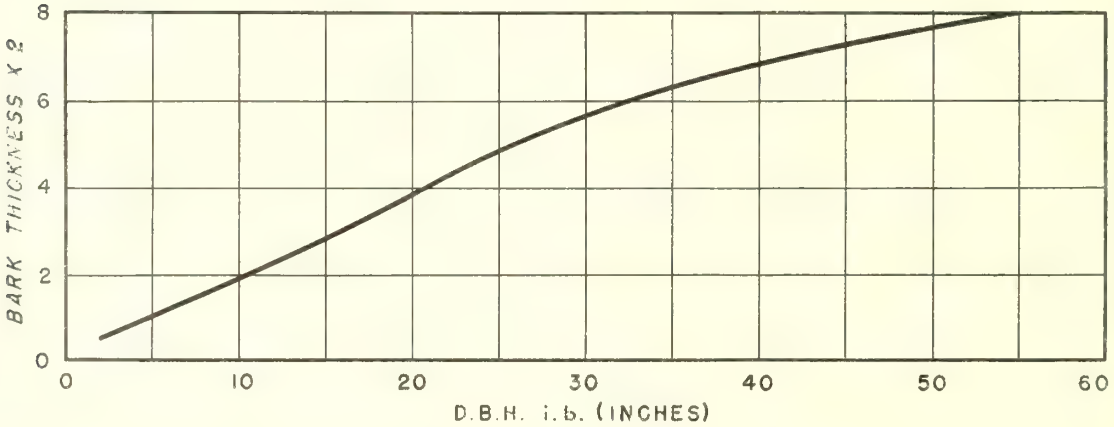

Fig. 6 — Double bark thickness in inches at B.H. by d.b.h. inside bark. (Based on 149 trees)

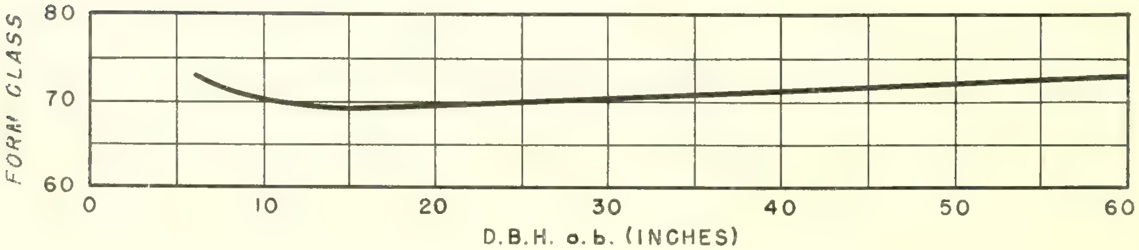

Fig. 7 — Form class by d.b.h. (Based on 150 trees)

Table 1.- Form-class Volume Table for Second-growth Redwood
BOARD FEET - SCRIBNER RULE
Form Class 70

D.B.H. in inches	Height in number of 16.3-foot logs utilized: 1	2	3	4	5	6	7	8	9	10	Minimum top d.i.b. utilized	Basis No. of trees
12	37	72	105								8	9
14	50	97	142								9	13
16	65	125	183	240							10	17
18	82	157	230	302	372						10	9
20	101	193	282	370	456	541					11	8
22	121	232	340	445	549	651					11	6
24	143	275	402	526	649	770	890				12	4
26		321	469	615	758	900	1040				12	8
28		370	542	710	875	1038	1200	1360			13	10
30		423	619	811	1000	1187	1372	1555			13	3
32		479	701	919	1133	1345	1554	1762			14	6
34		539	789	1033	1274	1512	1748	1981			14	8
36		602	881	1154	1423	1689	1952	2213	2472	2729	15	4
38		668	978	1282	1580	1875	2168	2457	2745	3030	15	4
40		738	1080	1415	1745	2071	2394	2714	3031	3346	15	2
42			1187	1556	1918	2276	2631	2983	3331	3678	16	1
44			1299	1702	2099	2491	2879	3264	3645	4025	16	3
46			1416	1855	2288	2715	3138	3557	3973	4386	17	1
48				2014	2484	2948	3407	3863	4314	4763	17	1
50				2180	2688	3190	3687	4180	4669	5155	18	-
52				2352	2900	3442	3978	4510	5037	5561	18	-
54				2530	3120	3703	4280	4852	5419	5983	18	-
56				2715	3348	3973	4592	5206	5815	6419	19	-
58				2906	3583	4253	4915	5572	6223	6871	19	-
60				3103	3826	4541	5248	5950	6646	7337	20	1
Trees	22	33	12	25	17	8	1	-	-	-		118

Stump height 18" on uphill side.

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

The equations from which the tabled volumes were obtained are as follows:
Logarithm b.f. vol. = 1.936,011 (logarithm d.b.h. in inches) + 0.939,164 (logarithm utilized length in feet) + 0.009,961 (form class) - 2.351,894.

Average deviation of individual tree volumes from values estimated by the equation is 3.9 percent.

Aggregate difference: Estimated values 0.19 percent low.

Table 1 (continued)

MULTIPLIERS FOR OTHER FORM CLASSES

Form class is 100 times d.i.b. top first log divided by d.b.h. o.b. Factors by which to multiply volumes in Form Class 70 table to obtain volumes for other form classes:

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
5	0.63	0.65	0.66	0.68	0.69	0.71	0.73	0.74	0.76	0.78
6	0.80	0.81	0.83	0.85	0.87	0.89	0.91	0.93	0.96	0.98
7	1.00	1.02	1.05	1.07	1.10	1.12	1.15	1.17	1.20	1.23
8	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.48	1.51	1.55

Example: Volume of 36", 5-log tree of form class 78 is 1423 x 1.20 = 1708.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

A. A. Hasel
February 1950

Additional copies of this table may be obtained from the California Forest and Range Experiment Station, Box 245, Berkeley 1, California.

Table 2. - Form-class Volume Table for Second-growth Redwood

BOARD FEET - INTERNATIONAL 1/4-INCH RULE
Form Class 70

D.B.H. in inches	Height in number of 16.3-foot logs utilized										Minimum top d.i.b. utilized	Basis No. of trees
	1	2	3	4	5	6	7	8	9	10		
12	44	83	122								8	9
14	58	111	162								9	13
16	74	142	208	272							10	17
18	92	177	258	339	418						10	9
20	112	215	314	411	507	602					11	8
22	133	256	374	491	605	718					11	6
24	157	301	440	576	711	843	975				12	4
26		348	510	668	824	978	1130				12	8
28		400	585	766	945	1121	1296	1469			13	10
30		454	664	870	1073	1274	1472	1669			13	3
32		512	749	981	1209	1435	1659	1880			14	6
34		572	837	1097	1353	1605	1855	2103			14	8
36		636	931	1219	1504	1784	2062	2338	2611	2883	15	4
38		703	1028	1347	1662	1972	2279	2583	2885	3186	15	4
40		773	1131	1481	1827	2168	2506	2840	3172	3502	15	2
42			1237	1621	1999	2372	2742	3108	3472	3833	16	1
44			1349	1767	2179	2586	2988	3387	3784	4177	16	3
46			1464	1918	2365	2807	3244	3677	4108	4535	17	1
48				2075	2559	3037	3510	3978	4444	4906	17	1
50				2238	2759	3275	3785	4290	4792	5290	18	-
52				2406	2967	3521	4069	4613	5152	5688	18	-
54				2580	3181	3775	4363	4946	5525	6099	18	-
56				2759	3402	4038	4667	5290	5909	6523	19	-
58				2944	3630	4308	4979	5645	6305	6960	19	-
60				3135	3865	4587	5301	6010	6712	7412	20	1
Trees	22	33	12	25	17	8	1	-	-	-		118

Stump height 18" on uphill side.
Block indicates extent of basic data.
Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.
The equations from which the tabled volumes were obtained are as follows:
Logarithm b.f. vol. = 1.848,446 (logarithm d.b.h. in inches) + 0.939,005 (logarithm utilized length in feet) + 0.009,548 (form class) - 2.162,583.
Average deviation of individual tree volumes from values estimated by the equation is 3.0 percent
Aggregate difference: Estimated values 0.19 percent low.

Table 2 (continued)

MULTIPLIERS FOR OTHER FORM CLASSES

Form class is 100 times d.i.b. top first log divided by d.b.h. o.b. Factors by which to multiply volumes in Form Class 70 table to obtain volumes for other form classes:

Form Class :	(Units)									
(Tens) :	0	1	2	3	4	5	6	7	8	9
5	0.64	0.66	0.67	0.69	0.70	0.72	0.74	0.75	0.77	0.79
6	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98
7	1.00	1.02	1.04	1.07	1.09	1.12	1.14	1.17	1.19	1.22
8	1.25	1.27	1.30	1.33	1.36	1.39	1.42	1.45	1.49	1.52

Example: Volume of 36", 5-log tree of form class 78 is 1504 x 1.19 = 1790.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

A. A. Hasel
February 1950

Additional copies of this table may be obtained from the California Forest and Range Experiment Station, Box 245, Berkeley 1, California.

Table 3.- Form-class Volume Table for Second-growth Redwood

CUBIC FEET IN SAWLOG PORTION

Form Class 70

D.B.H. in inches	Height in number of 16.3-foot logs utilized: 1	2	3	4	5	6	7	8	9	10	Minimum top d.i.b. utilized	Basis No. of trees
12	8.1	13.4	18.7								8	9
14	10.8	17.9	25.0								9	13
16	13.9	23.1	32.2	40.1							10	17
18	17.3	28.8	40.2	50.1	59.4						10	9
20	21.1	35.1	49.0	61.1	72.4	83.3					11	8
22	25.2	42.0	58.6	73.0	86.7	99.7					11	6
24	29.7	49.4	69.0	86.0	102.	117.	132.				12	4
26		57.4	80.2	100.	119.	136.	154.				12	8
28		66.0	92.2	115.	136.	157.	177.	196.			13	10
30		75.2	105.	131.	155.	179.	201.	223			13	3
32		84.9	119.	148.	175.	202.	227.	251.			14	6
34		95.1	133.	166.	196.	226.	254.	282.			14	8
36		106.	148.	184.	219.	252.	283.	314.	343.	372.	15	4
38		117.	164.	204.	242.	279.	313.	347.	380.	412.	15	4
40		129.	180.	225.	267.	307.	345.	382.	419.	454.	15	2
42			198.	246.	292.	336.	378.	419.	459.	497.	16	1
44			216.	269.	319.	367.	413.	458.	501.	543.	16	3
46			234.	292.	347.	399.	449.	497.	544.	590.	17	1
48				317.	376.	432.	486.	539.	590.	639.	17	1
50				342.	406.	467.	525.	582.	637.	690.	18	-
52				368.	437.	502.	565.	626.	686.	743.	18	-
54				395.	469.	539.	607.	672.	736.	798.	18	-
56				423.	502.	578.	650.	720.	788.	854.	19	-
58				452.	536.	617.	694.	769.	842.	913.	19	-
60				482.	572.	658.	740.	820.	897.	973.	20	1
rees	22	33	12	25	17	8	1	-	-	-		118

olume excluding bark.

tump height 18" on uphill side.

lock indicates extent of basic data.

orm Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

he equations from which the tabled volumes were obtained are as follows:
Logarithm cubic volume sawlog portion = 1.880,403 (logarithm d.b.h. in inches) + 0.766,659 (logarithm utilized length in feet) + 0.008,545 (form class) - 2.649,799.

verage deviation of individual tree volumes from values estimated by the equation is 3.5 percent.

ggregate difference: Estimated values 0.10 percent low.

Table 3 (continued)

MULTIPLIERS FOR OTHER FORM CLASSES

Form class is 100 times d.i.b. top first log divided by d.b.h. o.b. Factors by which to multiply volumes in Form Class 70 table to obtain volumes for other form classes:

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
5	0.67	0.69	0.70	0.72	0.73	0.74	0.76	0.77	0.79	0.81
6	0.82	0.84	0.85	0.87	0.89	0.91	0.92	0.94	0.96	0.98
7	1.00	1.02	1.04	1.06	1.08	1.10	1.13	1.15	1.17	1.19
8	1.22	1.24	1.27	1.29	1.32	1.34	1.37	1.40	1.42	1.45

Example: Volume of 36", 5-log tree of form class 78 is 219 x 1.17 = 256.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

A. A. Hasel
February 1950

Additional copies of this table may be obtained from the California Forest and Range Experiment Station, Box 245, Berkeley 1, California.

Table 4.- Form-class Volume Table for Second-growth Redwood
CUBIC FEET INSIDE BARK FROM TOP OF STUMP TO A 4-INCH I.B. TOP
Form Class 70

D.B.H.: in : inches:	Height in feet from ground on uphill side to tip																	: Basis : No. of : trees
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	
6	2.5	2.9	3.3	3.6														6
8	4.5	5.2	5.9	6.6	7.2													10
10	7.1	8.3	9.4	10.5	11.5	12.5												9
12	10.4	12.2	13.8	15.3	16.8	18.2	19.6											11
14	14.4	16.7	19.0	21.1	23.2	25.1	27.0											13
16	19.0	22.1	25.1	27.9	30.6	33.2	35.7											17
18		28.3	32.1	35.7	39.1	42.4	45.6	48.7	51.8									9
20		35.2	39.9	44.4	48.7	52.8	56.8	60.7	64.4	68.1	71.7	75.2						8
22		42.9	48.7	54.1	59.4	64.4	69.3	74.0	78.6	83.0	87.4	91.7	95.9					6
24		51.4	58.3	64.9	71.2	77.2	83.0	88.7	94.2	99.5	105.	110.	115.					4
26			68.9	76.6	84.1	91.2	98.1	105.	111.	118.	124.	130.	136.					8
28			80.4	89.4	98.1	106.	114.	122.	130.	137.	144.	151.	158.	165.	172.	178.	185.	10
30				103.	113.	123.	132.	141.	150.	158.	167.	175.	183.	191.	198.	206.	213.	3
32				118.	129.	140.	151.	161.	171.	181.	191.	200.	209.	218.	227.	235.	244.	6
34				134.	147.	159.	171.	183.	194.	205.	216.	227.	237.	247.	257.	267.	277.	8
36					165.	179.	193.	206.	219.	231.	244.	255.	267.	279.	290.	301.	312.	4
38					185.	201.	216.	231.	245.	259.	273.	286.	299.	312.	324.	337.	349.	4
40						223.	240.	257.	273.	288.	303.	318.	333.	347.	361.	375.	388.	2
42							266.	284.	302.	319.	336.	352.	368.	384.	399.	415.	430.	1
44							293.	313.	332.	351.	370.	388.	406.	423.	440.	457.	473.	3
46							322.	343.	365.	385.	406.	426.	445.	464.	483.	501.	519.	1
48							351.	375.	398.	421.	443.	465.	486.	507.	527.	547.	567.	1
50								408.	434.	458.	483.	506.	529.	552.	574.	596.	617.	-
52									471.	497.	524.	549.	574.	599.	623.	647.	670.	-
54										538.	566.	594.	621.	648.	674.	700.	725.	-
56										580.	611.	641.	670.	699.	727.	755.	782.	-
58											657.	689.	721.	752.	782.	812.	841.	-
60											705.	740.	773.	807.	839.	871.	902.	1
Trees	-	8	20	37	18	1	7	8	12	10	6	8	7	3	-	-	-	145

(See notes on reverse side)

Volume excludes bark and stump.

Stump heights measured from uphill side: 13" for 6" d.b.h., 15" for 8" d.b.h., 17" for 10" d.b.h., and 18" for 12" d.b.h. and larger.

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table on reverse side is for the average Form Class of the sample trees. Factors in the tabulation below are to be used to get volumes for other Form Classes.

The equations from which the tabled volumes were obtained are as follows:
Logarithm cubic volume to 4 inches i.b. = 2.081,127 (logarithm d.b.h. in inches) + 0.691,137 (logarithm total height in feet) + 0.010,285 (form class) - 3.055,417.

Average deviation of individual tree volumes from values estimated by the equation is 6.6 percent.

Aggregate difference: Estimated values 0.01 percent high.

MULTIPLIERS FOR OTHER FORM CLASSES

Form class is 100 times d.i.b. top first log divided by d.b.h. o.b. Factors by which to multiply volumes in Form Class 70 table to obtain volumes for other form classes:

Form Class :	(Units)									
(Tens) :	0	1	2	3	4	5	6	7	8	9
5	0.62	0.64	0.65	0.67	0.68	0.70	0.72	0.74	0.75	0.77
6	0.79	0.81	0.83	0.85	0.87	0.89	0.91	0.93	0.95	0.98
7	1.00	1.02	1.05	1.07	1.10	1.13	1.15	1.18	1.21	1.24
8	1.27	1.30	1.33	1.36	1.39	1.43	1.46	1.50	1.53	1.57

Example: Volume of 36", 150-foot tree of form class 78 is 255 x 1.21 = 308.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

A. A. Hasel
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Additional copies of this table may be obtained from the California Forest and Range Experiment Station, Box 245, Berkeley 1, California.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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BOARD-FOOT AND CUBIC-FOOT VOLUME TABLES FOR SOME CALIFORNIA HARDWOODS

By

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The tables presented here were prepared for estimating tree volumes of some of the most common hardwood species in California: California black oak (Quercus Kelloggii), Oregon white oak (Q. Garryana), Pacific madrone (Arbutus Menziesii), and tanoak (Lithocarpus densiflora). No tables existed previously for these species. The tables were prepared especially to meet the requirements of the nation-wide Forest Survey, but they should be useful also for general cruising.

Method of Construction

The tables were prepared by the logarithmic regression equation method[2] as applied to form-class tables by Buell[3]. This method expresses volume as a function of d.b.h., height, and form class.

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[1] Formerly members of the Division of Forest Economics, California Forest and Range Experiment Station.

[2] Schumacher, F. X., and Hall, F. Dos S. Logarithmic Expression of Timber-Tree Volume. Jour. Agric. Research 47:719 -733. 1933.

[3] Buell, J. H. Outside-bark Form Class Volume Tables for Some Southern Appalachian Species. Technical Note No. 53, Appalachian Forest Experiment Station, Asheville, North Carolina.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Measurements of each tree were plotted on Forest Service Tree Measurement Form 558a. Cubic volume was determined by planimetering on Form 558a. Total cubic volume includes the entire cubic volume of both the main stem and branches to a 4-inch top diameter, while the sawlog cubic volume is limited to the merchantable portion. Board-foot volumes were obtained by scaling the logs in the main stem and forks to a utilized top. The log scaling length was 8 feet plus trim allowance, while the utilized top diameter was never less than 10 inches inside bark. By definition, the minimum merchantable hardwood log was considered to be a log straight and sound enough to produce a 2" x 8" x 8' plank. The total cubic-foot tables include both sawlog trees and cordwood trees, the latter being trees that were too rough to contain a sawlog according to the preceding definition.

Form Class

Form class (Girard's) is the ratio of diameter inside bark at top of the first 16.3-foot log to d.b.h. outside bark, expressed as a percentage. This may be written algebraically:

$$\text{Form class} = \frac{\text{d.i.b. top of first 16.3-ft. log}}{\text{d.b.h. o.b.}} \times 100$$

Figure 1 (page 4) shows the relation of form class to d.b.h. for the sample trees used in preparing the tables. Whether this is a good general representation of the distribution of form class by diameter classes for these species is not known. Considering the limited basis for these curves the values shown should serve only as guides and not be used indiscriminately. Form class should be determined for each stand or locality where the tables are to be used.

Each volume table is prepared for the average form class of the sample trees on which it is based. Multipliers are given, however, for converting volumes to other form classes. By using the multipliers these tables can be readily adapted to fit any particular stand or size class by first determining the form class in the stand to be cruised.

How to Use the Tables

1. Determine form class for each species to be cruised. To get the form class of an individual tree, measure or estimate the taper outside bark from breast height to the top of the first 16-foot log and subtract this amount from d.b.h. to get d.o.b. at the top of the log. Measure bark thickness at the top of the first log if possible. Otherwise use table 13 to get the double bark thickness for the appropriate d.b.h. class and deduct this amount from d.o.b. top of first log to get d.i.b. Enter these values in the equation and compute form class.

> Example: Black oak measured d.b.h. o.b. is 24.3 inches, taper to top of first log is 5 inches, double bark thickness is 1.4 inches. Then, d.i.b. top first log = 24.3 - 5 - 1.4 = 17.9.

$$\text{Form class} = \frac{17.9}{24.3} \times 100 = 74\%$$

2. Determine form class on 50 or more trees representing the range of diameter classes for each species in the stand. Plot the average form class for each d.b.h. class as in figure 1. If form class is not related to d.b.h. then an average form class for the species may be used. If form class is definitely related to size of tree, the average form class for each d.b.h. class or group should be used in deriving a table by application of the multipliers.

> Example: Board-foot volume of 24.3-inch, 5 log black oak tree of form class 74 = 390 x 1.07 = 417.

3. If volumes by the International 1/4-inch rule are desired, the average factors for conversion from Scribner are given in table 14. Thus, for the 24.3-inch black oak in the above example, the volume by International 1/4-inch rule is 417 x 1.016 = 424 board feet.

4. The total cubic foot tables include the volume of the branches to a 4-inch inside bark minimum as well as of the main stem.

Factors are provided in table 15 for estimating cubic volume, exclusive of branchwood.

> Example: Black oak 30 inches d.b.h., total height 80 feet, form class 65, contains 134 cubic feet according to table 3. In table 15 the percentage indicated in branchwood is 15, so that the volume exclusive of branchwood is 134 - .15 (134) = 114 cubic feet.

Limitations of Data

Most of the data were collected along right-of-way clearings for power lines, telephone lines, and roads and therefore are representative of all trees in the stands sampled. The data meet requirements of Forest Survey in this respect but may or may not be representative of timber that is cruised for commercial cutting, where trees are selected to meet certain log-length or quality requirements.

Measurements were taken on trees in the following localities:

Mendocino County: Percy
Trinity County: Hayfork, Big Bar, Corral Creek, Browns Creek
Humboldt County: Garberville, Mattole, Bull Creek, Hartsook Inn
Del Norte County: Gasquet, Smith River
Josephine County, Oregon: Kirby, Selma

While the tables are based on a minimum of data, they are believed to be adequate for present purposes in the area represented. As opportunity is afforded, additional data should be collected covering more completely the range of each species. Any information regarding application of the tables in local areas and additional data that may be used to strengthen the tables will be welcomed by the authors.

Additional copies of these tables may be obtained from the California Forest and Range Experiment Station upon request.

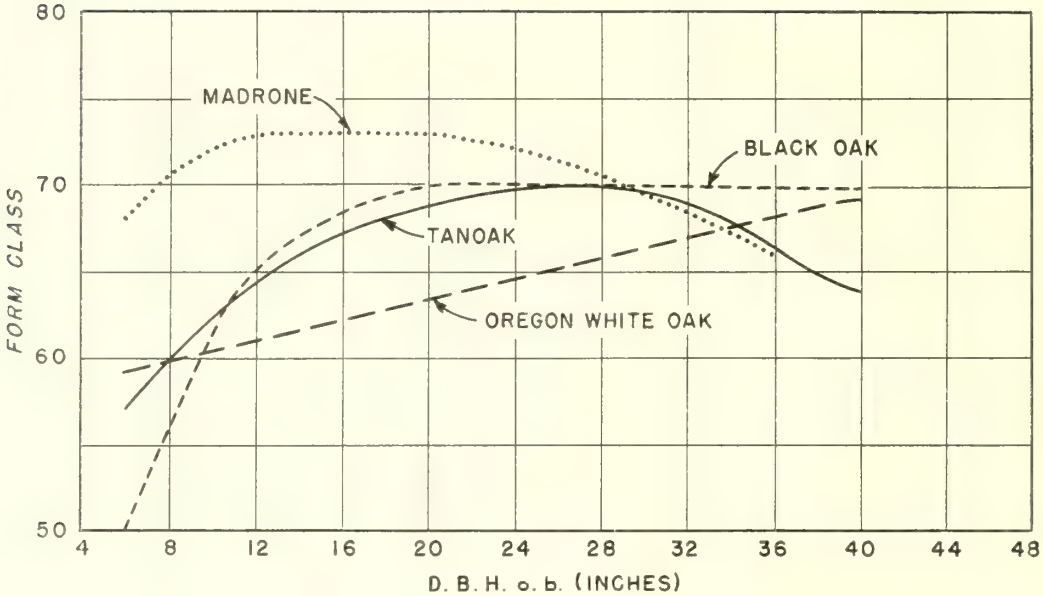

Figure 1. — Average form class by d.b.h. of the sample trees used in preparing the volume tables.

Table 1.- Form-class Volume Table for California Black Oak
BOARD FEET SCRIBNER DECIMAL C LOG RULE
Form Class 70

D.B.H. in Inches	Volume (board feet in tens) by number of 8-foot logs										Basis No. of trees
	1	2	3	4	5	6	7	8	9	10	
12	3	4									4
14	4	6	9	11							9
16	5	8	11	14	17	20					11
18	6	11	15	18	22	25					5
20	8	13	18	23	27	31	35				9
22	9	16	22	28	33	38	43	47			3
24	11	19	26	33	39	45	51	56	62		5
26	13	23	31	39	46	53	59	66	72	78	3
28	15	26	36	45	53	61	69	76	84	91	-
30		30	41	51	61	70	79	87	96	104	2
32		34	47	58	69	79	89	99	109	118	1
34		38	52	65	78	90	101	112	122	133	-
36		43	59	73	87	100	113	125	137	149	-
38			65	81	97	111	126	139	152	165	-
40			72	90	107	123	139	154	169	183	-
42			79	99	118	136	153	169	186	201	1
44				109	129	149	168	186	203	221	-
46				119	141	162	183	203	222	241	-
48				129	153	177	199	220	242	262	-
Basis	10	17	9	5	6	2	3	1	-	-	53

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm bd. ft. vol. = 1.9693 (logarithm d.b.h. inches) + 0.7718 (logarithm merch. ht. no. 8-ft. logs) + 0.0070 (form class) - 1.1544.

Basis: 53 trees measured in northwestern California.

Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches; scaled in 8-foot log lengths plus trimming allowance.

Average deviation of individual tree volumes from values estimated by the equation: ± 10.8 percent.

Aggregate difference: estimated values 0.08 percent high.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
	Factors									
5	0.72	0.74	0.75	0.76	0.77	0.79	0.80	0.81	0.82	0.84
6	0.85	0.86	0.88	0.89	0.91	0.92	0.94	0.95	0.97	0.98
7	1.00	1.02	1.03	1.05	1.07	1.08	1.10	1.12	1.14	1.16
8	1.17	1.19	1.21	1.23	1.25	1.27	1.29	1.32	1.34	1.36
9	1.38	1.40	1.43	1.45	1.47	1.50	-	-	-	-

Example: Volume of 34-inch, 6-log tree of form class 76 = 90 x 1.10 = 99.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

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Table 2.- Form-class Volume Table for California Black Oak
CUBIC FEET IN SAWLOG PORTION
Form Class 70

D.B.H.: in : inches:	Volume (cubic feet) by number of 8-foot logs									:Basis :No. of :trees
	1	2	3	4	5	6	7	8	9	
12	5.5	9.6	13.2							4
14	7.3	12.6	17.3	21.7						9
16	9.2	15.9	21.9	27.5	32.8					11
18	11.3	19.5	26.9	33.8	40.3	46.6				5
20	13.6	23.5	32.4	40.7	48.5	56.1	63.3			9
22	16.1	27.8	38.3	48.1	57.4	66.3	74.9	83.2		3
24	18.7	32.4	44.6	56.0	66.9	77.2	87.2	97.0	106.	5
26		37.3	51.4	64.5	77.0	88.9	100.	112.	122.	3
28		42.5	58.5	73.5	87.7	101.	114.	127.	140.	-
30		47.9	66.1	82.9	99.0	114.	129.	143.	157.	2
32			74.0	92.9	111.	128.	145.	161.	176.	1
34			82.3	103.	123.	142.	161.	179.	196.	-
36			91.0	114.	136.	157.	178.	198.	217.	-
38			100.	126.	150.	173.	196.	217.	239.	-
40				138.	164.	190.	214.	238.	261.	-
42				150.	179.	206.	233.	259.	284.	1
44					194.	224.	253.	281.	309.	-
46					210.	242.	274.	304.	334.	-
48					226.	261.	295.	328.	360.	-
Basis	10	17	9	5	6	2	3	1	-	53

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 1.7569 (logarithm d.b.h. inches) + 0.7907 (logarithm merch. ht. no. 8-ft. logs) + 0.0033 (form class) - 1.3834.

Basis: 53 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and forks between stump and utilized top. Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches.

Average deviation of individual tree volumes from values estimated by the equation: ± 6.19 percent.

Aggregate difference: estimated values 0.27 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
	Factors									
5	0.86	0.87	0.87	0.88	0.89	0.89	0.90	0.91	0.91	0.92
6	0.93	0.93	0.94	0.95	0.96	0.96	0.97	0.98	0.98	0.99
7	1.00	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.06	1.07
8	1.08	1.09	1.10	1.10	1.11	1.12	1.13	1.14	1.15	1.16
9	1.16	1.17	1.18	1.19	1.20	1.21	-	-	-	-

Example: Volume of 32-inch, 5-log tree of form class 80 =
111.0 x 1.08 = 119.9.

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

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Table 3.- Form-class Volume Table for California Black Oak
CUBIC FEET INSIDE BARK BETWEEN STUMP AND 4-INCH TOP I.B.
Form Class 65

D.B.H. in inches	Volume (cubic feet) by total height in feet									Basis No. of trees
	20	30	40	50	60	70	80	90	100	
6	1.7	2.1	2.5	2.8						2
8	3.2	4.0	4.7	5.3						7
10	5.3	6.7	7.8	8.8	9.7	10.6	11.4			7
12	8.0	10.0	11.7	13.2	14.6	15.9	17.1			8
14	11.3	14.1	16.6	18.7	20.7	22.5	24.2	25.8		13
16	15.3	19.1	22.3	25.2	27.9	30.4	32.7	34.8		12
18		24.9	29.1	32.9	36.3	39.5	42.5	45.4		5
20		31.5	36.8	41.6	46.0	50.1	53.9	57.5		9
22		39.0	45.6	51.6	57.0	62.0	66.7	71.2	75.4	3
24		47.4	55.5	62.7	69.3	75.4	81.1	86.5	91.6	5
26		56.7	66.4	75.0	82.9	90.2	97.1	104.0	110.0	4
28			78.4	88.6	97.9	107.0	115.0	122.	130.	-
30			91.5	103.	114.	124.	134.	143.	151.	2
32				120.	132.	144.	155.	165.	175.	1
34				137.	151.	165.	177.	189.	200.	-
36				156.	172.	187.	201.	215.	228.	-
38				176.	194.	211.	227.	242.	257.	-
40				197.	218.	237.	255.	272.	288.	-
42					243.	264.	284.	303.	321.	1
44					270.	294.	316.	337.	357.	-
46					298.	324.	349.	372.	394.	-
48					328.	357.	384.	409.	434.	-
Basis	2	3	18	17	12	17	6	4	-	79

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 2.2425 (logarithm d.b.h. inches) + 0.5482 (logarithm total ht. ft.) + 0.0047 (form class) - 2.5349.

Basis: 79 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and branches between stump and 4-inch top inside bark; stump height varied from 11 to 17 inches for trees up to 12 inches d.b.h., 18-inch stump for trees 12 or more inches d.b.h.

Average deviation of individual tree volumes from values estimated by the equation: ± 14.8 percent.

Aggregate difference: estimated values 0.06 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
					Factors					
4	0.76	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.83	0.84
5	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94
6	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04
7	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.15	1.16
8	1.18	1.19	1.20	1.22	1.23	1.24	1.26	1.27	1.28	1.30
9	1.31	1.32	1.34	1.35	1.37	1.38	-	-	-	-

Example: Volume of 30-inch, 80-foot tree of form class 75 =
134 x 1.11 = 148.7

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

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Table 4.- Form-class Volume Table for Oregon White Oak
BOARD FEET SCRIBNER DECIMAL C LOG RULE
Form Class 68

D.B.H.: in inches	Volume (board feet in tens) by number of 8-foot logs										Basis: No. of trees
	1	2	3	4	5	6	7	8	9	10	
12	3	5									4
14	4	7	9	12							12
16	6	9	12	15	18	20					8
18	7	12	15	19	22	25					7
20	9	14	19	23	27	31	34				12
22	10	17	23	28	33	37	41	45			4
24	12	20	27	33	39	44	49	54	58		1
26	14	23	31	38	45	51	57	63	68	73	3
28	17	27	36	44	52	59	66	72	79	85	2
30		31	41	50	59	67	75	83	90	97	4
32		35	47	57	67	76	85	93	102	110	2
34		39	52	64	75	86	95	105	114	123	-
36		44	58	72	84	96	107	117	127	137	1
38			65	80	93	106	118	130	141	152	-
40			72	88	103	117	130	143	156	168	-
42			79	96	113	128	143	157	171	184	-
44				105	123	140	157	172	187	202	-
46				115	134	153	171	188	204	220	-
48				125	146	166	185	204	221	238	-
Basis	14	15	15	10	4	2	-	-	-	-	60

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm bd. ft. vol. = 1.9195 (logarithm d.b.h. inches) + 0.7081 (logarithm merch. ht. no. 8-ft. logs) + 0.0064 (form class) - 0.9932.

Basis: 60 trees measured in northwestern California.

Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches; scaled in 8-foot log lengths plus trimming allowance.

Average deviation of individual tree volumes from values estimated by the equation: ± 10.6 percent.

Aggregate difference: estimated values 0.00 percent high or low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
					Factors					
5	0.77	0.78	0.79	0.80	0.81	0.83	0.84	0.85	0.86	0.88
6	0.89	0.90	0.92	0.93	0.94	0.96	0.97	0.99	1.00	1.01
7	1.03	1.05	1.06	1.08	1.09	1.11	1.13	1.14	1.16	1.18
8	1.19	1.21	1.23	1.25	1.27	1.28	1.30	1.32	1.34	1.36
9	1.38	1.40	1.42	1.45	1.47	1.49	-	-	-	-

Example: Volume of 34-inch, 6-log tree of form class 76 = 86 x 1.13 = 97.

Prepared by
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California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

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Table 5.- Form-class Volume Table for Oregon White Oak
CUBIC FEET IN SAWLOG PORTION
Form Class 68

D.B.H. in inches	Volume (cubic feet) by number of 8-foot logs 1	2	3	4	5	6	7	8	9	10	Basis No. of trees
12	6.0	9.7									4
14	8.0	12.9	17.0	20.7							12
16	10.2	16.4	21.7	26.5	30.8	35.0					8
18	12.7	20.4	26.9	32.8	38.3	43.4					7
20	15.3	24.7	32.6	39.8	46.4	52.6	58.4				12
22	18.3	29.4	38.9	47.3	55.2	62.6	69.5	76.2			4
24	21.4	34.5	45.6	55.5	64.7	73.4	81.5	89.4	96.9		1
26	24.8	39.9	52.7	64.3	74.9	84.9	94.4	103.	112.	121.	3
28	28.4	45.7	60.4	73.6	85.8	97.2	108.	118.	128.	138.	2
30		51.8	68.5	83.5	97.3	110.	123.	134.	146.	157.	4
32		58.3	77.1	94.0	110.	124.	138.	151.	164.	176.	2
34		65.2	86.1	105.	122.	139.	154.	169.	183.	197.	-
36		72.3	95.6	116.	136.	154.	171.	188.	203.	219.	1
38			106.	129.	150.	170.	189.	207.	224.	241.	-
40			116.	141.	165.	187.	207.	227.	247.	265.	1
42			127.	154.	180.	204.	227.	249.	269.	290.	-
44				168.	196.	222.	247.	271.	294.	316.	-
46				182.	213.	241.	268.	294.	318.	342.	-
48				197.	230.	260.	289.	317.	344.	370.	-
Basis	14	15	15	10	4	3	-	-	-	-	61

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 1.8280 (logarithm d.b.h. inches) + 0.6871 (logarithm merch. ht. no. 8-ft. logs) + 0.0041 (form class) - 1.4711.

Basis: 61 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and forks, between stump and utilized top. Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches.

Average deviation of individual tree volumes from values estimated by the equation: ± 8.7 percent.

Aggregate difference: estimated values 0.10 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
					Factors					
5	0.84	0.85	0.86	0.87	0.88	0.88	0.89	0.90	0.91	0.92
6	0.93	0.94	0.94	0.95	0.96	0.97	0.98	0.99	1.00	1.01
7	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11
8	1.12	1.13	1.14	1.15	1.16	1.17	1.19	1.20	1.21	1.22
9	1.23	1.24	1.25	1.27	1.28	1.29	-	-	-	-

Example: Volume of 32-inch, 5-log tree of form class 78 =
110 x 1.10 = 121

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

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Table 6.- Form-class Volume Table for Oregon White Oak

CUBIC FEET INSIDE BARK BETWEEN STUMP AND
4-INCH TOP I.B.
Form Class 63

D.B.H.: in : inches:	Volume (cubic feet) by total height in feet									:Basis :No. of :trees
	20	30	40	50	60	70	80	90	100	
6	1.4	1.8	2.2	2.5						13
8	2.9	3.7	4.4	5.0						11
10	4.9	6.3	7.5	8.6	9.6					9
12	7.7	9.8	11.7	13.3	14.9	16.3				9
14	11.2	14.3	17.0	19.4	21.6	23.7	25.7			17
16	15.5	19.7	23.5	26.8	29.9	32.8	35.6			9
18		26.3	31.2	35.7	39.9	43.7	47.4	50.9		7
20		33.9	40.4	46.2	51.5	56.5	61.2	65.7		12
22		42.8	50.9	58.2	64.9	71.2	77.2	82.8	88.2	4
24		52.9	62.9	71.9	80.2	88.0	95.3	102.	109.	1
26		64.3	76.4	87.4	97.5	107.	116.	124.	132.	3
28		76.9	91.5	105.	117.	128.	139.	149.	159.	2
30			108.	124.	138.	151.	164.	176.	187.	4
32			127.	145.	161.	177.	192.	206.	219.	2
34				168.	187.	205.	222.	239.	254.	-
36				193.	215.	236.	255.	274.	292.	1
38				220.	245.	269.	291.	313.	333.	-
40				249.	278.	305.	330.	354.	377.	1
42				280.	312.	343.	371.	399.	425.	-
44					350.	384.	416.	447.	476.	-
46					390.	428.	464.	498.	530.	-
48					432.	474.	514.	552.	588.	-
Basis	4	19	29	22	12	11	7	1	-	105

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 2.4306 (logarithm d.b.h. inches) + 0.6008 (logarithm total height ft.) + 0.0037 (form class) - 2.7519.

Basis: 105 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and branches between stump and 4-inch top inside bark; stump height varied from 11 to 17 inches for trees up to 12 inches d.b.h., 18-inch stump for trees 12 or more inches d.b.h.

Average deviation of individual tree volumes from values estimated by the equation: ± 17.2 percent.

Aggregate difference: estimated values 0.37 percent high.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	0	1	2	3	4	5	6	7	8	9
					Factors					
4	0.82	0.83	0.84	0.84	0.85	0.86	0.87	0.87	0.88	0.89
5	0.90	0.90	0.91	0.92	0.93	0.93	0.94	0.95	0.96	0.97
6	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.03	1.04	1.05
7	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15
8	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25
9	1.26	1.27	1.28	1.29	1.30	1.31	-	-	-	-

Example: Volume of 34-inch, 70-foot tree of form class 80 =
205 x 1.16 = 237.8

Prepared by:
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California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 7.- Form-class Volume Table for Pacific Madrone

BOARD FEET SCRIBNER DECIMAL C LOG RULE
Form Class 73

D.B.H.: in inches:	Volume (board feet in tens) by number of 8-foot logs									:Basis :No.of :trees
	1	2	3	4	5	6	7	8	9	
12	3	5	7							3
14	5	7	9	11						8
16	6	10	12	15	17					6
18	8	13	16	19	22	24				6
20	10	16	20	24	27	31	34	37		7
22	13	19	25	30	34	38	41	45		3
24		23	30	36	41	45	50	54	58	4
26		28	35	42	48	54	59	64	69	4
28		33	42	49	57	63	69	75	81	3
30		38	48	57	66	73	81	87	94	-
32			55	66	75	84	93	100	108	1
34			63	75	86	96	105	114	123	-
36			71	85	97	108	119	129	139	-
38			80	95	109	122	134	145	156	-
40			89	106	122	136	149	162	174	-
42			99	118	135	151	166	180	193	-
44			110	131	149	167	183	199	213	-
46			121	144	164	184	202	218	235	-
48			132	157	180	201	221	239	257	-
Basis	6	8	10	6	6	6	2	1	-	45

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm bd. ft. vol. = 2.1450 (logarithm d.b.h. inches) + 0.6047 (logarithm merch. ht. no. 8-ft. logs) + 0.0065 (form class) - 1.2478.

Basis: 45 trees measured in northwestern California.

Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches; scaled in 8-foot log lengths plus trimming allowance.

Average deviation of individual tree volumes from values estimated by the equation: ± 9.8 percent.

Aggregate difference: estimated values 0.19 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
	Factors									
5	0.71	0.72	0.73	0.74	0.75	0.76	0.78	0.79	0.80	0.81
6	0.82	0.84	0.85	0.86	0.87	0.89	0.90	0.91	0.93	0.94
7	0.96	0.97	0.99	1.00	1.02	1.03	1.05	1.06	1.08	1.09
8	1.11	1.13	1.14	1.16	1.18	1.20	1.21	1.23	1.25	1.27
9	1.29	1.31	1.33	1.35	1.37	1.39	-	-	-	-

Example: Volume of a 34-inch, 5-log tree of form class 66 = 86 x 0.90 = 77.

Prepared by:
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California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 8.- Form-class Volume Table for Pacific Madrone
CUBIC FEET IN SAWLOG PORTION
Form Class 73

D.B.H. in inches	Volume (cubic feet) by number of 8-foot logs: 1	2	3	4	5	6	7	8	9	Basis No. of trees
12	6.0	9.9	13.4							3
14	7.8	13.0	17.6	21.7						8
16	9.9	16.5	22.2	27.5	32.4					6
18	12.2	20.3	27.3	33.8	39.9	45.6				6
20	14.6	24.4	32.9	40.7	48.0	54.9	61.5	67.8		7
22	17.3	28.8	38.9	48.1	56.7	64.9	72.7	80.2		3
24		33.6	45.3	56.0	66.1	75.6	84.7	93.4		4
26		38.7	52.2	64.5	76.0	87.0	97.5	108.	117.	4
28		44.1	59.4	73.5	86.6	99.1	111.	123.	134.	3
30		49.7	67.0	82.9	97.7	112.	125.	138.	151.	-
32			75.1	92.9	110	125.	140.	155.	169.	1
34			83.5	103.	122.	139.	156.	172.	188.	-
36			92.4	114.	135.	154.	173.	190.	208.	-
38			102.	126.	148.	169.	190.	209.	228.	-
40			111.	137.	162.	185.	208.	229.	250.	-
42			121.	150	176.	202.	226.	250.	272.	-
44			131.	162.	192.	219.	246.	271.	296.	-
46			142.	176.	207.	237.	265.	293.	320.	-
48			153.	189.	223.	255.	286.	316.	344.	-
Basis	6	8	10	6	6	6	2	1	-	45

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 1.7562 (logarithm d.b.h. inches) + 0.7378 (logarithm merch. ht. no. 8-ft. logs) + 0.0028 (form class) - 1.3241.

Basis: 45 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and forks between stump and utilized top. Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches.

Average deviation of individual tree volumes from values estimated by the equation: ± 6.6 percent.

Aggregate difference: estimated values 0.03 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	(Units)									
	0	1	2	3	4	5	6	7	8	9
	Factors									
5	0.86	0.87	0.87	0.88	0.88	0.89	0.90	0.90	0.91	0.91
6	0.92	0.93	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97
7	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.03	1.03	1.04
8	1.05	1.05	1.06	1.07	1.07	1.08	1.09	1.09	1.10	1.11
9	1.12	1.12	1.13	1.14	1.14	1.15	-	-	-	-

Example: Volume of 32-inch, 5-log tree of form class 80 =
110 x 1.05 = 115.5

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 9.- Form-class Volume Table for Pacific Madrone
CUBIC FEET INSIDE BARK BETWEEN STUMP AND
4-INCH TOP I.B.
Form Class 68

D.B.H. in inches	Volume (cubic feet) by total height in feet										Basis No. of trees
	20	30	40	50	60	70	80	90	100	110	
6	2.0	2.4	2.7	3.0							8
8	3.9	4.7	5.3	5.9	6.4						3
10	6.6	7.9	8.9	9.9	10.7	11.5					9
12	10.0	12.0	13.6	15.1	16.3	17.5	18.6				6
14		17.1	19.4	21.5	23.3	25.0	26.5	28.0			8
16		23.3	26.5	29.2	31.7	34.0	36.1	38.1	39.9		6
18		30.5	34.8	38.4	41.7	44.7	47.4	50.0	52.4	54.7	6
20			44.3	49.0	53.1	57.0	60.5	63.7	66.8	69.7	7
22			55.2	61.0	66.2	71.0	75.4	79.4	83.3	86.9	3
24			67.5	74.6	81.0	86.8	92.1	97.1	102.	106.	4
26			81.3	89.8	97.5	104.	111.	117.	123.	128.	4
28			96.4	107.	116.	124.	132.	139.	145.	152.	3
30				125.	136.	145.	154.	163.	170.	178.	-
32				145.	157.	169.	179.	189.	198.	207.	1
34				167.	181.	194.	206.	217.	228.	238.	-
36				190.	207.	221.	235.	248.	260.	271.	1
38					234.	251.	266.	281.	294.	307.	-
40					264.	282.	300.	316.	331.	346.	-
42					295.	316.	336.	354.	371.	387.	-
44					329.	352.	374.	394.	413.	431.	1
46					364.	390.	414.	437.	458.	478.	-
48					401.	430.	457.	481.	505.	527.	-
Basis	1	5	10	9	11	17	12	2	3	-	70

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 2.3098 (logarithm d.b.h. inches) + 0.4481 (logarithm total ht. ft.) + 0.0042 (form class) - 2.3746.

Basis: 70 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and branches between stump and 4-inch top inside bark; stump height varied from 11 to 17 inches for trees up to 12 inches d.b.h., 18-inch stump for trees 12 or more inches d.b.h.

Average deviation of individual tree volumes from values estimated by the equation: ± 11.6 percent.

Aggregate difference: estimated values 0.55 percent high.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
	Factors									
4	0.74	0.75	0.76	0.76	0.77	0.78	0.79	0.79	0.80	0.81
5	0.82	0.82	0.83	0.84	0.85	0.86	0.86	0.87	0.88	0.89
6	0.90	0.91	0.92	0.93	0.93	0.94	0.95	0.96	0.97	0.98
7	0.99	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08
8	1.09	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.18	1.19
9	1.20	1.21	1.23	1.24	1.25	1.26	-	-	-	-

Example: Volume of 26-inch, 80-foot tree of form class 76 =
111 x 1.05 = 116.6

Prepared by
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 10.- Form-class Volume Table for Tanoak
BOARD FEET SCRIBNER DECIMAL C LOG RULE
Form Class 68

D.B.H. in inches	Volume (board feet in tens) by number of 8-foot logs											Basis No. of trees
	1	2	3	4	5	6	7	8	9	10	11	
12	2	4	6									-
14	3	6	9	11	14							5
16	4	7	11	14	17	20						4
18	5	9	13	17	21	25	29					8
20	6	11	16	21	26	30	35	39				9
22	7	13	19	25	30	36	41	46	52			7
24	8	15	22	29	35	42	48	54	60	66	72	5
26		18	26	33	41	48	55	62	69	76	83	6
28		20	29	38	46	55	63	71	79	87	95	4
30		23	33	43	53	62	71	80	89	98	107	2
32			37	48	59	69	80	90	100	110	120	4
34			41	54	66	77	89	100	112	123	134	2
36			46	59	73	86	98	111	124	136	148	1
38			50	65	80	94	108	122	136	150	163	1
40			55	72	88	103	119	134	149	164	179	1
42				78	95	113	129	146	162	179	195	-
44				85	104	122	141	159	176	194	212	-
46				92	112	132	152	172	191	210	229	-
48				99	121	143	164	185	206	226	247	-
Basis	3	5	9	13	8	9	3	2	2	4	1	59

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm bd. ft. vol. = 1.7747 (logarithm d.b.h. inches) + 0.9038 (logarithm merch. ht. no. 8-ft. logs) + 0.0051 (form class) - 0.8792.

Basis: 59 trees measured in northwestern California.

Stump height 18 inches; top diameter inside bark as utilized but never less than 10 inches; scaled in 8-foot log lengths plus trimming allowance.

Average deviation of individual tree volumes from values estimated by the equation: ± 6.4 percent.

Aggregate difference: estimated values 0.24 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class (Tens)	(Units) 0	1	2	3	4	5	6	7	8	9
					Factors					
5	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90
6	0.91	0.92	0.93	0.94	0.95	0.97	0.98	0.99	1.00	1.01
7	1.02	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.14
8	1.15	1.16	1.18	1.19	1.21	1.22	1.24	1.25	1.26	1.28
9	1.29	1.31	1.33	1.34	1.36	1.37	-	-	-	-

Example: Volume of a 30-inch, 6-log tree of form class 76 = 62 x 1.10 = 68.

Prepared by
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 11.- Form-class Volume Table for Tanoak
CUBIC FEET IN SAWLOG PORTION
Form Class 68

D.B.H.: in inches:	Volume (cubic feet) by number of 8-foot logs											:Basis :No.of :trees
	1	2	3	4	5	6	7	8	9	10	11	
12	4.6	7.8	10.6									-
14	6.1	10.6	14.1	17.5	20.8							5
16	7.8	13.2	18.0	22.4	26.6	30.6						4
18	9.7	16.4	22.4	27.9	33.1	38.1	42.8					8
20	11.8	20.0	27.2	34.0	40.3	46.3	52.1	57.7				9
22	14.0	23.8	32.5	40.5	48.1	55.2	62.1	68.8	75.3			7
24	16.5	28.0	38.2	47.6	56.5	64.9	73.0	80.9	88.5	95.9	103.	5
26		32.5	44.3	55.2	65.5	75.3	84.7	93.8	103.	111.	120.	6
28		37.3	50.9	63.4	75.2	86.4	97.2	108.	118.	128.	137.	4
30		42.4	57.8	72.0	85.4	98.2	110.	122.	134.	145.	156.	2
32			65.2	81.2	96.3	111.	125.	138.	151.	164.	176.	4
34			72.9	90.8	108.	124.	139.	154.	169.	183.	197.	2
36			81.0	101.	120.	138.	155.	172.	188.	203.	219.	1
38			89.6	112.	132.	152.	171.	190.	207.	225.	242.	1
40			98.5	123.	146.	167.	188.	209.	228.	247.	266.	1
42				134.	159.	183.	206.	228.	250.	271.	291.	-
44				147.	174.	200.	225.	249.	272.	295.	317.	-
46				159.	189.	217.	244.	270.	296.	321.	345.	-
48				172.	204.	235.	264.	292.	320.	347.	373.	-
Basis	3	5	9	13	8	9	3	2	2	4	1	59

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 1.8542 (logarithm d.b.h. inches) + 0.7644 (logarithm merch. ht. no. 8-ft. logs) + 0.0075 (form class) - 1.8517.

asis: 59 trees measured in northwestern California.

olume is cubic foot contents, excluding bark, of main stem and forks between stump and utilized top. Stump height 18 inches; top diameter inside bark as utilized but not less than 10 inches.

verage deviation of individual tree volumes from values estimated by the equation ± 6.0 percent.

ggregate difference: estimated values 0.01 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
	Factors									
5	0.73	0.75	0.76	0.77	0.79	0.80	0.81	0.83	0.84	0.86
6	0.87	0.89	0.90	0.92	0.93	0.95	0.97	0.98	1.00	1.02
7	1.04	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.19	1.21
8	1.23	1.25	1.27	1.30	1.32	1.34	1.36	1.39	1.41	1.44
9	1.46	1.49	1.51	1.54	1.57	1.59	-	-	-	-

Example: Volume of 30-inch, 6-log tree of form class 76 =
98.2 x 1.15 = 112.9

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 12.- Form-class Volume Table for Tanoak
CUBIC FEET INSIDE BARK BETWEEN STUMP
AND 4-INCH TOP I.B.
Form Class 65

D.B.H. in inches	Volume (cubic feet) by total height in feet 20	30	40	50	60	70	80	90	100	110	120	Basis No. of trees
6	1.2	1.6	2.0	2.4								4
8	2.2	3.0	3.7	4.4	5.1	5.7						3
10	3.5	4.8	6.0	7.1	8.1	9.1						5
12	5.2	7.1	8.8	10.4	12.0	13.5	14.9	16.3				5
14	7.2	9.9	12.2	14.5	16.6	18.7	20.7	22.6	24.5			11
16		13.1	16.3	19.3	22.1	24.8	27.5	30.0	32.5			4
18		16.8	20.9	24.8	28.4	31.9	35.3	38.6	41.8	44.9		8
20		21.1	26.2	31.0	35.6	40.0	44.2	48.3	52.3	56.2		9
22		25.8	32.1	38.0	43.6	49.0	54.2	59.2	64.1	68.9		7
24			28.6	45.7	52.4	58.9	65.2	71.3	77.2	82.9	88.6	5
26			45.8	54.2	62.2	69.9	77.3	84.5	91.5	98.4	105.	6
28			53.6	63.5	72.9	81.9	90.5	99.0	107.	115.	123.	4
30			62.1	73.5	84.4	94.8	105.	115.	124.	133.	142.	2
32				84.4	96.8	109.	120.	132.	142.	153.	164.	4
34				96.0	110.	124.	137.	150.	162.	174.	186.	2
36				108.	124.	140.	155.	169.	183.	197.	210.	-
38				122.	140.	157.	174.	190.	205.	221.	236.	2
40				136.	156.	175.	194.	212.	229.	246.	263.	1
42				150.	173.	194.	215.	235.	254.	273.	292.	-
44				166.	191.	214.	237.	259.	281.	302.	322.	-
46				183.	210.	236.	261.	285.	309.	332.	354.	-
48				200.	230.	258.	285.	312.	338.	363.	388.	-
Basis	-	2	5	9	11	15	18	6	8	3	5	82

Block indicates extent of basic data.

Form Class: Diameter inside bark at top of first 16.3-foot log divided by diameter outside bark at breast height, the result being multiplied by 100. Table above is for the average Form Class of the sample trees. Factors in the tabulation on the reverse side are to be used to get volumes for other Form Classes.

Table constructed from the equation: Logarithm cubic ft. vol. = 2.1300 (logarithm d.b.h. inches) + 0.7560 (logarithm total ht. ft.) + 0.0092 (form class) - 3.1624.

Basis: 82 trees measured in northwestern California.

Volume is cubic foot contents, excluding bark, of main stem and branches between stump and 4-inch top inside bark; stump height varied from 11 to 17 inches for trees up to 12 inches d.b.h., 18-inch stump for trees 12 or more inches d.b.h.

Average deviation of individual tree volumes from values estimated by the equation: ± 10.9 percent.

Aggregate difference: estimated values 0.06 percent low.

MULTIPLIERS FOR OTHER FORM CLASSES

Factors by which to multiply volumes in the average table to obtain volumes for other Form Classes

Form Class	(Units)									
(Tens)	0	1	2	3	4	5	6	7	8	9
	Factors									
4	0.59	0.60	0.61	0.63	0.64	0.65	0.67	0.68	0.70	0.71
5	0.73	0.74	0.76	0.78	0.79	0.81	0.83	0.84	0.86	0.88
6	0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.07	1.09
7	1.11	1.14	1.16	1.18	1.21	1.24	1.26	1.29	1.32	1.35
8	1.37	1.40	1.43	1.46	1.50	1.53	1.56	1.59	1.63	1.66
9	1.70	1.73	1.77	1.81	1.85	1.89	-	-	-	-

Example: Volume of 30-inch, 80-foot tree of form class 75 =
105 x 1.24 = 130.2

Prepared by:
Division of Forest Economics
California Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Table 13.- Double bark thickness at top of first 16.3-foot log[1]

D.B.H. o.b. (inches)	Double bark thickness, inches			
	Black oak	Oregon white oak	Pacific madrone	Tanoak
8	0.4	0.4	0.2	0.6
10	0.5	0.5	0.3	0.8
12	0.7	0.6	0.3	1.0
14	0.8	0.7	0.4	1.2
16	0.9	0.7	0.4	1.4
18	1.1	0.8	0.4	1.6
20	1.2	0.8	0.4	1.7
22	1.3	0.9	0.4	1.8
24	1.4	0.9	0.5	2.0
26	1.5	0.9	0.5	2.0
28	1.6	0.9	0.5	2.1
30	1.7	0.9	0.5	2.2
32	1.7	1.0	0.5	2.2
34	1.8	1.0	0.5	2.2
36	1.9	1.0	0.5	2.3
38	1.9	1.0	0.5	2.3
40	2.0	1.0	0.5	2.3
42	2.1	1.0	0.5	2.4
44	2.1	1.0	0.5	2.4
46	2.2	1.0	0.5	2.4
48	2.2	1.0	0.5	2.5

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[1] Measured from uphill side with a stump height of 15 inches for trees 8 inches d.b.h., 17 inches for trees 10 inches d.b.h., and 18 inches for larger sizes. This places the point of measurement at 17.8 feet above the ground for trees 12 inches d.b.h. and over.

Table 14.- Converting factors for some California hardwoods

D.B.H. Inches	Board feet Scribner to International 1/4" (multiply)
12	1.037
14	1.031
16	1.026
18	1.022
20	1.019
22	1.017
24	1.016
26	1.014
28	1.013
30	1.012
32	1.012
34	1.011
36	1.010
38	1.010
40	1.010
42	1.009
44	1.009
46	1.009
48	1.009

Basis: 274 trees, including red alder, golden chinquapin, California laurel, Pacific madrone, bigleaf maple, black oak, Oregon white oak, interior live oak, and tanoak.

Table 15.- Proportion of total cubic volume of main stem and branches, to 4-inch top, that occurs in branches[1]

D.B.H. in Inches	Black oak	Oregon white oak	Pacific madrone	Tanoak
	Percent			
6	0.0	0.0	0.0	0.0
8	3.2	7.0	0.8	0.0
10	6.0	11.2	2.2	0.5
12	8.0	14.4	4.5	1.1
14	9.7	16.6	7.2	1.6
16	10.9	18.5	8.3	2.0
18	12.0	19.9	10.8	2.3
20	12.7	21.0	12.3	2.6
22	13.4	21.8	13.2	2.8
24	13.8	22.5	14.0	3.0
26	14.3	23.0	14.5	3.2
28	14.6	23.4	14.7	3.4
30	14.8	23.6	14.9	3.5
32	14.9	23.7	15.0	3.6
34	15.0	23.7	15.1	3.7
36	15.0	23.8	15.2	3.8
38	15.1	23.8	15.3	3.9
40	15.1	23.9	15.4	3.9
42	15.1	23.9	15.5	3.9
44	15.1	24.0	15.5	4.0
46	15.1	24.0	15.5	4.0
48	15.1	24.0	15.5	4.0
No. of trees	79	105	71	81

[1] Total cubic volume includes volume of main stem and branches, excluding bark, between stump and 4-inch top inside bark.

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

Research Note No. 69 June 1, 1950

CHECK LIST FOR INSPECTION OF LUMBER DRY KILNS

By Harvey H. Smith, Forest Products Technologist

Lumber dry kilns are production machines that require careful attention and maintenance to keep them in good working order. Too often, too much is taken for granted regarding their general operating condition, and they fall into a state of disrepair that makes good drying difficult or outright impossible. This note suggests one type of check list that may be used as a guide for use by the kiln operator or other qualified person in making routine inspections of buildings and equipment. Management may also find this form useful in having inspections made and reported at regular intervals.

The need for such regular inspection was forcefully revealed by kiln certification studies of all types of kilns, made during the war by technicians from the Forest Products Laboratory, Madison, Wisconsin. Many kilns could not meet the established requirements because poor maintenance or faulty adjustment of kiln parts made accurate control of temperature and humidity impossible. This study provided the basis for the attached check list.

Periodic examination of the kiln building and kiln equipment may reveal faulty conditions that can be corrected immediately at little cost. Neglect of these conditions can lead to expensive repairs or replacements. For example, poor drying may result from as simple an oversight as failure to replace the wet-bulb wick regularly, thus allowing the old wick to become incrusted with debris that results in faulty humidity control. Lack of proper air baffles, either because of omission from the original installation or because of poor repair of existing equipment, may lead to greatly reduced air circulation through the loads of lumber. Leaks in the steam heating and spray systems may waste steam and necessitate excessive venting. Water-logged coils and traps may result in uneven heating throughout the kiln, which in turn will cause uneven drying. Such examples can be cited for most of the items listed in the check list.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

KILN INSPECTION CHECK LIST

(Where maintenance or replacement is recommended, indicate kiln number.)

AIR CIRCULATION SYSTEM

1. Fans and motors, present condition:
   Condition of electrical connections and switches:
   What maintenance or replacement is recommended:

2. Shafts and bearings, present condition:
   Are motor and shaft bearings properly lubricated:
   What maintenance or replacement is recommended:

3. Fan baffles, present condition:
   What maintenance or replacement is recommended:

4. Load baffles, present condition:
   Can load baffles be improved:
   What maintenance or replacement is recommended:

5. Air passageways
   Are air passageways open and unobstructed:
   Could air movement be improved:
   What maintenance or replacement is recommended:

HEATING AND HUMIDIFYING SYSTEM

1. Feed lines and header, present condition:
   Are they properly insulated:
   What maintenance or replacement is recommended:

2. Heating coils, present condition:
   Are all pipes open to full flow of steam:
   Condition of supports:
   What maintenance or replacement is recommended:

3. Traps, present condition:
   Are traps in best possible location:
   What maintenance or replacement is recommended:

4. Hand valves and automatic control valves, present condition:
   Are hand valves provided for blowing out coils:
   Are hand valves provided for shutting off individual coils:
   Are check valves working properly:
   What maintenance or replacement is recommended:

5. Spray lines, present condition:
   Are spray holes or nozzles open:
   Does condensate from spray line drip on lumber:
   What maintenance or replacement is recommended:

(over)

II. HEATING AND HUMIDIFYING SYSTEM (continued)

6. Vents, present condition: ____________
   Do vents open and close properly: ____________
   What maintenance or replacement is recommended: ____________

III. CONTROL SYSTEM

1. Recorder-controller, present condition: ____________
   Is recorder-controller properly calibrated: ____________
   Are capillary tubes protected: ____________
   Are bulbs properly located and mounted for accurate readings of kiln conditions: ____________
   What maintenance or replacement is recommended: ____________

2. Water supply
   Is water supply line to wet bulb open: ____________
   Is wet-bulb water pan clean: ____________
   Is drain line from water pan open: ____________
   Is wet-bulb wick replaced regularly: ____________
   What maintenance or replacement is recommended: ____________
3. Air supply
   Is supply adequate, clean, and uninterrupted: ____________
   Is compressor in good condition: ____________
   Are water and grease traps in good condition: ____________
   What maintenance or replacement is recommended: ____________

IV. BUILDING

1. Doors, present condition: ____________
   What maintenance or replacement is recommended: ____________

2. Walls, present condition: ____________
   Is protective coating adequate: ____________
   What other maintenance is recommended: ____________

3. Ceilings, present condition: ____________
   Is protective coating adequate: ____________
   What other maintenance is recommended: ____________

4. Floors and walkways, present condition: ____________
   What maintenance or replacement is recommended: ____________

5. Rails and supports, present condition: ____________
   What maintenance or replacement is recommended: ____________

V. GENERAL CONDITIONS OF YARD AND KILNS

Are yard tracks and transfer in good condition: ____________
Are kiln trucks in good condition: ____________
What maintenance or replacement is recommended: ____________

Are kilns and surrounding area neat and clean: ____________

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 70 June 12, 1950

[illegible]

SOME OBSERVATIONS ON THE SEEDFALL OF SUGAR PINE

By

H. A. Fowells

Forester

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Agriculture--Berkeley

SOME OBSERVATIONS ON THE SEEDFALL OF SUGAR PINE

By H. A. Fowells

Increasing interest in the management of sugar pine (Pinus lambertiana Dougl.) in the mixed-conifer stands of the west slope of the Sierra Nevada has pointed out the need of certain silvical knowledge. One bit of required knowledge is the area that can be seeded effectively by a sugar pine tree. The forest manager must have this information in marking a stand to obtain natural reproduction of sugar pine.

Observations by Siggins[1] give some notion of the horizontal distribution of seed. He found that sugar pine seed fell at the average rate of 8.7 feet per second in still air. Given the distance of fall and the wind velocity over the path of fall, the horizontal travel of falling seed can be computed. As wind velocity within the forest is extremely variable[2], any estimates of seed distribution based on assumed wind movements would no doubt be subject to large errors. Such estimates, however, can be used to set limits of seedfall. For example, seed falling 100 feet with an average wind velocity of 10 miles per hour theoretically would travel 169 feet horizontally. In view of the usually low wind velocities, such a distance may represent the upper limits of seed distribution.

This report concerns data collected at the Stanislaus Experimental Forest, California Forest and Range Experiment Station, on the actual distribution of sugar pine seed and on the amount of such seed necessary for natural reproduction.

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[1] Siggins, Howard W. 1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128.

[2] Fons, W. L. 1940. Influence of forest cover on wind velocity. Jour. Forestry 38: 481-486.

How Seed Distribution was Measured

To sample the distribution of seed from individual trees, seed traps were placed around three isolated sugar pine trees in 1941, a year of heavy seed production. The selected trees were long-crowned, 40 to 50 inches d.b.h., and 150 to 175 feet in height. They bore an average of about 150 cones apiece.

The seed traps, slightly less than 3 feet square, were exposed at the rate of 2 per square chain. To effect the location, 4 annuli, or concentric zones, of 8 square chains each were described around each tree, using radii of 1.59, 2.26, 2.76, and 3.19 chains. Then the circular area of 3.2 acres surrounding each tree was divided into octants. This division made 32 chain-square segments, within each of which two traps were located by random azimuths and distances.

Seeds falling in the traps were counted at 10-day intervals in October. All seeds were cut to determine soundness, and the distribution of sound seed only is reported.

How the Seed was Distributed

Sound seed, which constituted 91 percent of the total, fell on the 3.2 acres surrounding each tree at the average rate of 8,250 seed per acre. However, seedfall was concentrated close to the tree; 65 percent was in the first zone, and the remainder was about equally distributed in the three outer zones:

Zone	Radial distance chains	Seed per acre
First	0 - 1.59	21,400
Second	1.59 - 2.26	3,650
Third	2.26 - 2.76	4,300
Fourth	2.76 - 3.19	3,650

As to direction of fall, the seed was distributed fairly uniformly around the trees, despite strong east to northeast winds in one day of the first counting period. On the average, the proportion of seed falling in each octant was:

Octant	Proportion of total, percent
North northeast	9
East northeast	14
East southeast	7
South southeast	11
South southwest	21
West southwest	11
West northwest	17
North northwest	10

Of the total seed trapped, 78 percent had fallen by the first count, October 9; 17 percent in the next 10 days, and 5 percent in the last 10 days.

How Much Seed is Needed?

Large amounts of seed seem to be necessary to obtain relatively few seedlings even when favorable soil conditions are prepared before seedfall. In 1948 the California Station conducted a logging experiment[3] designed specifically for natural reproduction of sugar pine. Sound sugar pine seed fell on the test area at the rate of 29,000 per acre. On the basis of counts on 680 milacre quadrats, sugar pine seedlings germinated at the rate of 707 per acre. The area was treated to control rodents.

Other tests showed similar results. In 1941, sugar pine seedlings germinated at the rate of 139 per acre on bare mineral soil after sound seed fell at 10,600 per acre. In 1936, another good seed year, seed trap counts indicated that sugar pine seed was distributed at the rate of 29,100 seed per acre on one brushy, cut-over plot and 5,100 seed per acre on another. Seedlings were found the year after at the rate of 240 and 20 per acre respectively.

If these data are indicative of the amount of seed necessary to obtain a few hundred natural seedlings, then only within a radius of about 100 feet of the study trees was enough seed dispersed. In clearings much more than 100 feet from a seed tree natural regeneration of sugar pine may be scanty even in heavy seed years.

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[3] Dunning, Duncan. 1949. In, A sugar pine regeneration experiment. West Coast Lumberman 76(3): 62, 64.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director

No. 71 June 27, 1950

WET WATER FOR FOREST FIRE SUPPRESSION[1]

By

Wallace L. Fons, Mechanical Engineer

In recent years wetting agents have been recommended by manufacturers and others for increasing the efficiency of water for fire suppression. Many local fire-protection agencies have made tests comparing wetting agent solutions with plain water for flame suppression and mop-up under field conditions. In general, their results and conclusions indicated the need for comprehensive tests to determine the types of wetting agents best suited for suppression and the best technique for application of chemically treated water, called wet water.

Such comprehensive research was begun in 1948 by the Engineering Department at the University of California at Los Angeles. Technical supervision of the research was administered by the Division of Forest Fire Research, California Forest and Range Experiment Station. In 1949 the Station took over all phases of the investigative work.

At the outset it was realized that a great deal of fundamental research would be necessary before specifications on all phases of suppression could be developed. For instance, those physical properties of water and chemicals accounting for the suppression action were not known. The research program was therefore divided into three parts: (1) Determining the physical properties of plain water and wet water; (2) investigating the mechanisms of fire suppression; (3) determining the suppression effectiveness of wet water over plain water.

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[1] Presented at: Annual meeting, Southern California Association of Foresters and Fire Wardens, San Bernardino, Calif., April 7, 1950, and Annual meeting, California Rural Fire Association, Merced, Calif., April 21, 1950.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Physical Properties

The physical properties thought to be important in suppression are: surface tension, penetration, surface spreading, and foaming. Surface tension is a measure of the force required to hold a liquid drop in a spherical form. For instance, mercury has a high surface tension value (513 dynes/cm); water, a moderate value (72.8 dynes/cm); and alcohol and petroleum, low values (approximately 25 dynes/cm). Most wetting agents in concentration of one percent will reduce surface tension of water to 30 dynes/cm. The more active the wetting agent is, the more rapidly the surface tension of water is decreased. The recommended concentration for fire fighting is usually such as to reduce the surface tension of water to about 35 dynes/cm.

When the surface tension of water is reduced, spreading, penetrating, and foaming are increased. Tests of these physical properties were made on water and 14 commercial wetting agents. The tests show that:

1. Surface spreading of wet water on wood is 2 to 8 times greater than water, depending on species of wood.
2. Penetration into wood of wet water is about 8 times greater than water.
3. Penetration of wet water into charcoal is about 2/3 as much as it is for wood.
4. Penetration and surface spreading of water on charcoal is practically nil.
5. All wet water readily forms foam.

Corrosion tests with iron and galvanized iron showed that wetting agent solutions in general, unless they contain an inhibitor, have higher corrosion rates than distilled water. With few exceptions the rate of corrosion was greater for the galvanized iron. The corrosion of metals by wetting agent solutions may be wholly corrected by the addition of small amounts of chemicals, known as corrosion inhibitors, such as potassium dichromate and sodium nitrite. Tests showed that as little as 100 parts per million, or about 2 ounces per 100 gallons of water, of commercial granular potassium dichromate was effective in reducing the corrosion of iron and galvanized iron by wetting agent solutions.

Suppression Mechanism

Before tests with fires were begun, some important questions arose concerning the suppression action of water. First, what is the behavior of a water droplet when it strikes a burning wood surface? Calculations revealed that water, sprayed on burning wood with its surface reduced to charcoal, will impinge on the charcoal surface having a temperature as high as 1900° F. Second, what is the theoretical minimum volume of water necessary to cool a unit volume of burning wood below the rekindling point? Again, calculations showed that a unit volume of water suddenly applied over the entire surface will cool 300 volumes of burning wood below the kindling point; but if the water is applied only to the frontal area of the burning wood, the amount of water required is doubled. Third, does penetration cooling have an advantage over surface cooling and vice versa? Results of calculations indicated that there was no significant difference between penetration and surface cooling.

Suppression Effectiveness

Water may be used to an advantage in forest fire suppression for: (1) Flame suppression; that is, application of water on the flame to retard the spread of a given section of fire; (2) mop-up; that is, application of water on a burned area to extinguish small isolated flames and to cool glowing and charred material to a point at which rekindling is unlikely; (3) pretreatment; that is, application of water on unburned fuels in advance of an oncoming fire to retard its rate of spread or in holding a line from which to backfire. For each of these uses, fire tests were conducted to compare the suppression effectiveness of wet water ana plain water.

Flame Suppression

For flame suppression, a total of 93 model fires were burned on which the effectiveness of 14 commercial wetting agents were tested. Besides these laboratory tests, 66 field-fire tests were made, in which three commercial wetting agents were tested. Each fire was allowed to burn up to its maximum flame intensity before suppression was started. The intensity of each fire was measured with a radiometer. From the radiometer record of each fire, the intensity during suppression was calculated.

The experimental work established the superiority of wet water over plain water in reduction of fire intensity. The superiority is at its maximum when the liquid is first sprayed on the fire. Results indicate that this superiority at the very beginning of spray application on a section of flaming front is from three to four times greater than at the end of application, when only isolated flames remain. For the period of flame suppression of these experimental fires, the mean superiority values of wet water over plain water are 1.70 for field fires and 2.10 for model fires. Ordinarily, superiority is expressed as a ratio of quantity of plain water used to quanitty of chemical solution used. The superiority of wet water based on quantities was 1.25 for field fires and 1.55 for model fires.

However, in recommending wet water for flame suppression emphasis is given to the superiority based on reduction of flame intensity. The practical importance of this superiority, especially at the beginning of suppression, is that it shows the decided advantage a hose operator has in advancing on a fire front with wet water. This advantage should permit an operator to knock down the flame intensity more quickly to a point where he can move in and hold the spread of a fire. It is believed, therefore, that the use of wet water in flame suppression should result in controlling a greater number of fires as well as in controlling the fires at an earlier period, thus reducing the size of the mop-up job. Even where an abundant supply of water is available, use of wet water in some instances may make the difference between success and failure in controlling a forest fire.

In these tests the ratios of volume of burning wood to volume of wet water used for flame suppression were: field fires, 56 to 1; model fires, 117 to 1. For fires suppressed with water the ratios were 45 to 1 for field fires and 76 to 1 for model fires. These ratios, when compared with 300 to 1--the maximum possible, show that there is room for improvement in techniques of application.

Experimental work has not yet advanced sufficiently to specify what pressures and discharge rates to use for most efficient flame suppression. It has been noted, however, that on the experimental fires sprays were superior to straight streams primarily because of their greater coverage.

Mop-up

To test the effectiveness of wet water in mopping up fires in deep pine litter, a total of 108 test fires were burned. The technique used in mopping up these fires consisted of first spraying the burned area as rapidly as possible, suppressing all glowing, smoking, and burning material; yet not wasting water or wet water by wetting the area unnecessarily. In this first application care was taken to hold the nozzle above the surface of the burning litter at a distance which gave minimum air entrainment and effective spray distribution with maximum coverage. The first application was followed by an intermittent application on those spots where smoke appeared. A quick-opening-and-closing shut-off nozzle permitted closing the nozzle quickly when moving from one smoldering spot to another and opening it only long enough to extinguish the immediate small hot area.

The results of 82 of these fires show that the superiority based on quantity of plain water used compared to quantity of wet water used is about 1.29. Thus, by the addition of wetting agents at appropriate concentration, a saving of 23 percent in the quantity of water can be realized on a given mop-up job. As intermittent application was used part of the time in mopping up these fires, the superiority of wetting agent solutions based on time of mop-up is only 1.15. This means a saving of 13 percent in time in mopping up a given burn. In practice the saving of 23 percent in quantity of water and 13 percent in mop-up time may appear as not being significant; however, on a national scale or even on one large burn such a saving can amount to a considerable sum of money.

Another factor of practical importance is that wet water in mop-up has a distinct advantage in reducing the rekindling from hot spots and glowing embers. For the mop-up tests in deep pine litter the ratio of rekindled spots on plots suppressed with water to the rekindled spots on plots suppressed with wet water was 1.43 to 1. For comparable fuel types one can expect approximately 30 percent fewer rekindlings on an area mopped up with wet water.

Pretreatment

Pretreatment experiments were made by spraying wet water and plain water on litter fuels to determine whether wet water would increase the length of time that wetting is effective. The results of these experiments indicate that the length of time for sprayed unburned litter fuels to dry is 50 percent longer for wet water than for plain water. This is attributed to the greater surface spreading and penetration of wet water.

Conclusions

Significant differences were found in physical properties among the wetting agent solutions tested. However, no special meaning can be attached to these differences because these same agents were not significantly different in their effectiveness in the fire suppression tests. It appears that the surface spreading, penetrating, and foaming properties of all the wetting agents tested, when the agent is used so as to reduce the surface tension of plain water by one-half, are within that range which does not alter the effectiveness of a wetting agent solution for fire suppression. The results indicate that on the basis of penetration and surface spreading, any one of the hundreds of wetting agents now on the market, if used at the proper concentration, would yield suppression-effectiveness results comparable to those obtained for the wetting agents tested.

Specific conclusions drawn from work performed to date are: (1) Savings up to 23 percent in the volume of water required and 13 percent in time of mop-up can be obtained with wet water if applied with reasonable efficiency; (2) rekindling is reduced as much as 30 percent on fires mopped up with wet water as compared with plain water; (3) foaming appears to be a desirable property of wet water in mop-up because it prevents channeling of the water; (4) wet water is markedly superior to plain water in its ability to knock down flames quickly, thus permitting access to a fire edge not otherwise accessible; (5) dead fuels along the burning edge of a fire or along a backfire line remain wet up to 50 percent longer when sprayed with wet water than when sprayed with plain water; (6) fuels once treated with wet water and allowed to dry may be sprayed later with plain water with results comparable to an original spraying with wet water; (7) most wetting agents increase the corrosive action of water, but this can be wholly corrected by the addition of chemicals known as corrosion inhibitors.

In general, the results to date have shown that wetting agents have a definite place in forest fire suppression. Certain information on foaming and dermatological effects, however, is still needed to permit the writing of definite specifications for the most desirable type of wetting agents. Some advancement has been made on technique of application for maximum effectiveness; but this knowledge is not yet complete enough to satisfy all field conditions. Experiments are still needed to determine the effect of form and pattern of spray on fire suppression efficiency, for plain water, wetting agent solutions, and other chemicals.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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EFFECT OF WEED COMPETITION UPON SURVIVAL OF PLANTED PINE AND CHAPARRAL SEEDLINGS

By

J. S. Horton, Ecologist

Survival of trees and shrubs in field plantings[1/] under semi-arid conditions may be determined by the amount of competition for soil moisture and nutrients caused by plants growing in or near the planting area. An opportunity to study the effect of competition between annual plants and planted trees and shrubs was afforded in 1944 on the San Dimas Experimental Forest in southern California. The San Dimas lysimeters[2/] were soon to be planted to a number of species of native chaparral, and test plantings were made in an adjacent area over a period of several years to develop the proper method of establishing the desired vegetation. The test plantings, made in January, 1944, were designed to answer the question: "Will it be necessary to remove the cover of annual vegetation in order to establish a successful plantation?" The study reported here shows that weeding is necessary.

[1/] The term "planting" as used in this paper includes both the sowing of seeds and the planting of nursery grown stock.

[2/] "The San Dimas Lysimeters", by E. A. Colman and E. L. Hamilton, California Forest and Range Experiment Station, Research Note No. 47, 1947.

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Agriculture--Berkeley

Four species were used for the study: Coulter pine (*Pinus coulteri* D. Don), California scrub oak (*Quercus dumosa* Nutt.), hoaryleaf ceanothus (*Ceanothus crassifolius* Torr.), and chamise (*Adenostoma fasciculatum* H. and A.). The test was made in a soil that ranged from sandy loam to sandy clay loam in texture, and from 4 to 6 feet in depth. Growing conditions were good, due to the considerable depth of soil and the abundant winter rainfall (table 1). Average annual rainfall at the study area is 28 inches.

Table 1.- *Rainfall at Tanbark Flat, San Dimas Experimental Forest*

Month	1943-44	1944-45	1945-46
	Inches		
October	1.26	1.41	1.18
November	.37	9.41	.53
December	9.79	1.67	13.13
January	1.62	6.73	.39
February	13.96	3.17	2.33
March	3.48	5.33	8.03
April	1.75	.47	.00
May	.00	.00	.16
June	.36	.00	.00
July	.50	.00	.00
August	.00	.51	.00
September	.00	.00	.00
Total annual	32.59	28.70	25.75

The herbaceous growth that covered the test area had been undisturbed for 4 years prior to the study, and had developed a uniformly dense cover. *Bromus mollis* L., *B. arenarius* Labill., *B. rubens* L., *B. tectorum* L., *Festuca megalura* Nutt., *Lotus strigosus* (Nutt) Green, *Trifolium microcephalum* Pursh., and *Erodium circutarium* L'Her. were the most common species. All these are annuals that mature in the late spring or early summer. *Lotus strigosus* and *Trifolium microcephalum* may continue to grow as late as August if there is available water. For the sake of brevity, these annual grasses and herbs will be referred to in this paper as "weeds".

The plants to be studied were set out in the test plots as follow:

Pinus coulteri.-- Pine seedlings grown one year in a nursery seed bed were planted in nine rectangular plots of 50 seedlings each. The seedlings were placed in holes spaced 1 foot apart which were dug with a 2-inch soil auger. The individual plots measured 5 by 10 feet, and were arranged in a row alternating with unplanted strips 4 feet wide. The first, fourth, and seventh plots were hoed and kept free of competing weeds throughout the experiment; those weeds which developed in the second, fifth, and eighth plots were kept clipped to a height of 2 inches above the ground; the weeds in the third, sixth, and ninth plots were allowed to grow without hoeing or clipping.

Quercus dumosa.-- Scrub oak was planted by two methods; first, two square plots were planted with 100 seed spots, each spot containing three acorns, and second, two plots were planted with 25 bareroot transplants which had been grown 1 year in pots in the nursery, and removed from the nursery soil just prior to planting. In both methods, one of the two plots was kept free of weeds for the full period of the experiment, but on the other plot the weedy cover was allowed to grow without disturbance. The seed spots were covered with a litter layer and the entire sown area covered with woven wire to protect the seeds from birds and rodents.

Ceanothus crassifolius.--Seeds of hoaryleaf ceanothus were sown in two square plots of 100 seed spots each with approximately 30 seeds per spot. One plot was kept bare and the other allowed to stay weedy. Seed spots were covered with litter and the entire sown area covered with woven wire.

Adenostoma fasciculatum.-- Chamise seedlings dug from a 2-year-old burn were planted in two plots of 80 seedlings each (one kept bare and one left weedy). These plants were uniformly pruned to a 2-inch height after planting.

Survival counts of all species were made at intervals during the next three years.

Survival of Plants

Nearly all of the Coulter pine trees survived in the bare plots, only one dying out of the 150 planted (table 2). In the clipped plots 95 survived out of 150 planted, and in the weedy plots only 64. Most of the deaths occurred the first year between July and the end of December. Thus some deaths occurred after the abundant rains of November 1944. Very few deaths occurred during 1945 and 1946. In general deaths started earlier in the weedy plots than in those that were clipped.

Table 2.- Number of Coulter pine seedlings surviving out of initial planting of 50 per plot

Plot	Plot treatment	1944 7/22	1944 8/17	1944 8/30	1944 9/27	1944 10/19	1945 1/3	1945 4/5	1945 11/16	1946 10/9
1	Bare	50	50	50	49	49	49	49	49	49
2	Clipped	50	47	43	33	26	24	22	21	21
3	Weedy	43	27	22	11	7	3	3	2	2
4	Bare	50	50	50	50	50	50	50	50	50
5	Clipped	50	49	47	44	43	41	41	41	41
6	Weedy	49	47	45	42	41	41	41	39	39
7	Bare	50	50	50	50	50	50	50	50	50
8	Clipped	50	50	48	43	38	37	35	33	33
9	Weedy	50	49	47	38	32	27	26	23	23

The other species tested (table 3) showed qualitatively the same results, but in all cases survival of transplants in the bare plots was lower than was shown by the Coulter pine. Seed-spot germination and survival was determined by the number of spots that contained one or more living plants at the time of observation. Oak seedlings appeared in fewer seed-spots in the weedy plot than in the bare plot, and the seed-spots showed lower survival and greater second-year losses than did the transplants. Ceanothus showed the lowest seed-spot germination and survival. No seeds germinated in the weedy plot of this species.

Table 3.- Survival of three chaparral species, by type of planting, treatment, and date of examination

Species	Type of planting	Plot treatment	Germination	Date of observation 10/19/44	11/20/45	10/9/46
			Pct.	Pct.	Pct.	Pct.
Quercus dumosa	Trans-planting	Bare	--	88	84	84
		Weedy	--	44	36	36
	Seed spots	Bare	96	55	29	29
		Weedy	67	41	23	23
Ceanothus crassifolius	Seed spots	Bare	48	30	26	26
		Weedy	0	0	0	0
Adenostoma fasciculatum	Trans-plants	Bare	--	65	59	59
		Weedy	--	35	31	31

Discussion and Conclusion

The results of this study show that the presence of weeds reduced survival of all species. The first year appears to be the critical one in determining survival. The fact that most of the pine losses occurred during the dry late summer and fall suggests that competition for water between pine and weeds was probably the causative factor. This suggestion is substantiated by the fact that survival in the clipped plots of Coulter pine was greater than in the weedy plots; transpiration from the clipped weeds would be expected to be less than from the weeds that were growing freely.

In order to find out if differences in available water might provide a clue to the survival of the pines, soil moisture samples were taken on August 29, 1944, in each of the pine plots. This sampling provided a measurement of soil moisture at a time when air temperatures were high and soil moistures near to their minimum. The results of this sampling provided some substantiation of the idea that lack of available water was the critical factor in survival (table 4).

Table 4.- Available water and wilting point of the soils in the Coulter pine plots at the end of the first summer

Plot	Treatment	Soil layer							
		0-12 in.		12-24 in.		24-36 in.		36-48 in.	
		AW[1]	WP[2]	AW	WP	AW	WP	AW	WP
		- - - - - - - - - - - - Percent moisture - - - - - - - - - - - -							
1	Bare	-1.4	5.3	1.8	4.3	3.9	4.4	5.3	5.4
2	Clipped	-3.1	5.9	1.3	4.4	3.7	4.1	4.6	5.8
3	Weedy	-2.8	5.4	0.0	4.4	2.4	4.2	4.5	4.1
4	Bare	-1.5	4.8	0.8	4.7	2.9	4.9	4.2	4.0
5	Clipped	-1.6	7.2	1.4	6.6	3.3	4.4	4.9	4.2
6	Weedy	-1.6	7.4	1.0	6.0	4.6	5.9	5.8	9.0
7	Bare	-1.8	7.4	0.4	5.2	1.7	7.6	3.6	8.0
8	Clipped	-2.2	7.2	-0.3	5.5	3.3	8.4	7.5	7.2
9	Weedy	-2.2	6.6	-0.7	6.1	0.0	6.6	5.7	8.1

1/ AW = Available water (moisture content minus wilting point)

2/ WP = Wilting point

In every plot, regardless of treatment, the first foot of soil was devoid of water available to plants. The weedy plots were, on the average, somewhat drier than the bare plots in this layer. Available water was present in the second foot of some plots and not of others. Thus in the first and third trios of plots there was considerably less available water in the weedy than in the bare plots, but in the second trio this was not the case. The average available moisture for the second foot layer of the bare plots was 1.0 percent, for the clipped plots 0.8 percent, and for the weedy plots 0.1 percent. Available water was present in the third foot of all but one weedy plot, and every plot had abundant water in the fourth foot.

Certainly, death of plants cannot be blamed upon lack of water at soil depths greater than 2 feet. There was abundant water in the 2- to 4-foot layer, even at the close of summer. More likely, death was due to some condition in the top two feet of soil (which held most of the absorbing roots) during the spring growing period. At that time the weeds were in their most active growing condition and it can be assumed that transpiration rates were high in both weeds and planted stock. It appears likely that toward the end of that period soil water became scarce in the active root zone and competition for water became severe. Although many plants did not die until much later in the year, they were probably so weakened by weed competition in late spring that they were unable to survive the summer drought.

The study has shown that under conditions of summer drought, good survival of planted stock is dependent upon removal (at least during the first season) of competing annual grasses and herbs.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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CONTROL OF SPROUTING OF TANOAK AND MADRONE STUMPS[1]

by

G. H. Schubert

In part of the high-site-quality pine and fir types of California, stand improvement cuttings are made especially difficult by the sprouting habit of tanoak (Lithocarpus densiflora Hook. and Arn.) and madrone (Arbutus menziesii Pursh.). The stumps of these species sprout so vigorously that release of the favored crop trees is only temporary. How to control this sprouting on areas dedicated to production of conifers was the object of a small test on the Challenge Experimental Forest.

Treatment

Ten trees of each species were felled on five dates, first in late June 1947, then in July, August, and October, and in early June, 1948. Stump heights were 12 inches or lower. Stump diameter of madrones ranged from 3.6 inches to 10.4 inches, and of tanoaks from 3.8 inches to 11.9 inches. On each date half of the stumps were treated with 2,4-D; the range of diameters was about equally represented in treated and untreated stumps.

Treated stumps were drenched with a one percent water solution of the isopropyl ester of 2,4-D. Stumps smaller than 6 inches in diameter received ½ pint of solution; those larger received 1 pint. This dosage, purely arbitrary, gave good drenching of all stumps. The solution was applied immediately after the tree was felled.

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[1] This study was conducted under the direction of Duncan Dunning, in charge of Forest Management Research.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Results

Treatment with 2,4-D prevented sprouting of some stumps and reduced the number of sprouts per stump on the others. The proportions of treated and untreated stumps bearing sprouts were:

	Treated	Untreated
Madrone	28 percent	96 percent
Tanoak	64 percent	100 percent

These data show that treatment was more effective on madrone than on tanoak. The stumps that sprouted bore the following numbers of sprouts:

	Treated	Untreated
Madrone	6	19
Tanoak	19	45

Treatment thus reduced the sprouting capacity of the stumps if the stumps were not completely killed. The height of tallest sprouts was not appreciably different between the treated and untreated stumps.

Season of treatment did not greatly affect control of sprouting. The data suggest that treatment in midsummer may be best to prevent sprouting of madrone, and late fall or early spring treatment may be best for tanoak. However, the difference in control between the species for one season or another is not definitely proven. Obviously, season of cutting did not affect sprouting of the untreated stumps: practically all sprouted.

There was no correlation between diameter of stump and lack of sprouting or number of sprouts per stump. This lack of relationship suggests that the two levels of dosage may have been in excess of the amount required.

One practical application of these results is as a follow-up measure when cutting fuel wood. Madrone, in particular, often is cut for campwood by stand-by fire crews or other crews. Where release of pines is possible cutting for fuel wood followed by this simple treatment of the stumps will result in stand improvement.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
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EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director

No. 75 September 20, 1950

FURTHER EXPERIMENTS IN SEASONING CALIFORNIA BLACK OAK

By H. H. Smith, Forest Products Technologist

The forest and lumber economy of California is based on the utilization of softwoods: ponderosa and sugar pines, redwood, Douglas-fir, and several other species. The hardwoods of the region have been utilized to only a limited extent. In recent years, however, interest has increased in closer utilization of the more promising hardwoods. Most hardwoods season less easily than do the softwoods. This fact apparently has led to the belief that the California hardwoods could not be seasoned without prohibitive drying degrade. Recent research in the seasoning of California black oak has shown that such a broad conclusion is not correct, for this species at least can be seasoned successfully.

PREVIOUS WORK

The first seasoning experiments of California black oak by the California Forest and Range Experiment Station were completed in the fall of 1948.[1] Because of the widespread belief that this oak could not be seasoned, the test material was sawed into 3/4-inch flooring strips, 3 inches and 6 inches wide. There appeared to be a reasonable chance for success in the experimental drying of these thin, narrow strips.

The flooring strips dried readily, without drying defects, both on the air-drying yard and in the dry kiln after being air dried. But these results had limited application. They only suggested that drying might succeed with thicker stock. Full 1-inch lumber is the thinnest size usually sawed for general use, so some work on stock thicker and wider than the flooring strips seemed desirable. A second series of tests was scheduled, and the results are reported here.

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[1] Reported in Forest Research Note No. 62, California Forest and Range Experiment Station, 8 pp., July 1949.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

TEST MATERIAL

The California black oak for this series of seasoning experiments was cut in August of 1949 in an area 30 miles northeast of Oroville, at an elevation of 2,500 to 3,000 feet. Seven trees were felled and bucked into 13 logs, from 10 to 16 feet in length. The logs were delivered by truck to a local mill where they were sawed on a circular head-saw into 4/4, random, width lumber. The boards were edged, but end-trimmed on one end only.

PILING FOR AIR DRYING

The green oak lumber was delivered to the Oroville yard of the High Sierra Pine Company where it was put over the green chain for grading and tallying. The grader was unable to grade by the National Hardwood Lumber Association rules for inspection, but a board measure was made and recorded. This measure showed a total of 4,200 board feet of lumber from the 7 trees (13 logs), which gives an average of 600 board feet per tree, or 323 board feet per log.

The rough, green lumber was piled in unit packages for air drying, using nine 1- by 2-inch stickers per course. A bottom, or foundation course of 8/4 white fir was laid down first in piling each unit of oak lumber. This precaution was believed advisable in order to keep the oak as flat and straight as possible.

The unit packages were moved with a fork-lift truck to the air drying yard where they were stacked three high on good pile foundations. Cover boards were placed over the top units to protect the lumber from the direct sun.

The three piles of oak lumber were further protected by piling units of pine on both sides, spacing all the piles 12 to 18 inches apart. The space between adjacent rows of piles was about 8 feet. Thus, surrounding piles of pine protected the oak from the full effects of the hot winds that prevailed in the area during the time the lumber was on the yard.

(Greater care is required in piling hardwood lumber for air drying than in piling softwood. Nine or more stickers are usually required. A diagram showing a method for piling unit packages of hardwoods and a diagram prepared by the U. S. Forest Products Laboratory for hand-piling hardwood lumber on the yard are attached to this report.)

MEASURING THE RATE OF DRYING

Sample boards were pulled while the lumber was moving over the green chain. These samples were selected to represent both fast drying and slow drying boards as well as others that appeared to be average in all respects.

Twelve samples were placed in the units of lumber on the yard in spaces or pockets provided for the purpose. Oven-dry weights of these samples were calculated to facilitate periodic moisture content determination.[2]

The samples were weighed and carefully examined periodically during the air drying period.

Specially prepared wood slivers, approximately 1/8-inch thick, 4 inches wide and 18 inches long were placed within the loads of lumber. A measure of the moisture content to which the lumber would dry within the pile was obtained by weighing these samples.

AIR DRYING RESULTS

The results of the air drying can be stated very simply without qualifying and limiting explanation: the results were excellent.

Surface checking did not develop as expected during the air drying. No good explanation is readily available, for there were many wide, flat-sawed boards that might be expected to check when exposed to the relatively severe air drying conditions that prevailed.

End checking was moderate to slight, far less than expected. The end checking in the oak was no more severe than in adjacent piles of pine, and little if any loss would result from end trim necessitated by the checking.

During the total drying time of 63 days on the yard (fig. 1), the average moisture dropped from 98.5 percent (maximum of 113 percent) to 17.3 percent (maximum of 26 percent). The usual air-drying time for eastern white and red oak is 70 to 240 days, the time being dependent on the season of the year, of course. For the eastern oak the average moisture loss (based on the shorter drying time) is approximately 1 percent per day. The average moisture loss for the California black oak was more than 1½ percent per day. Besides drying rapidly as compared to the rate for eastern oak, the California black oak dried on the yard under relatively severe drying conditions without defects.

KILN DRYING RESULTS

After preliminary runs in a small experimental dry kiln[3] to determine what temperatures and humidities could be used, the bulk of the material was dried in a commercial steam-heated kiln of conventional cross-circulation design.

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[2] "The Use of Kiln Samples in the Operation of a Lumber Dry Kiln," U. S. Forest Products Laboratory report R1607.

[3] "Small Demountable-type Lumber Dry Kiln for Experimental Drying," U. S. Forest Products Laboratory publication R1671.

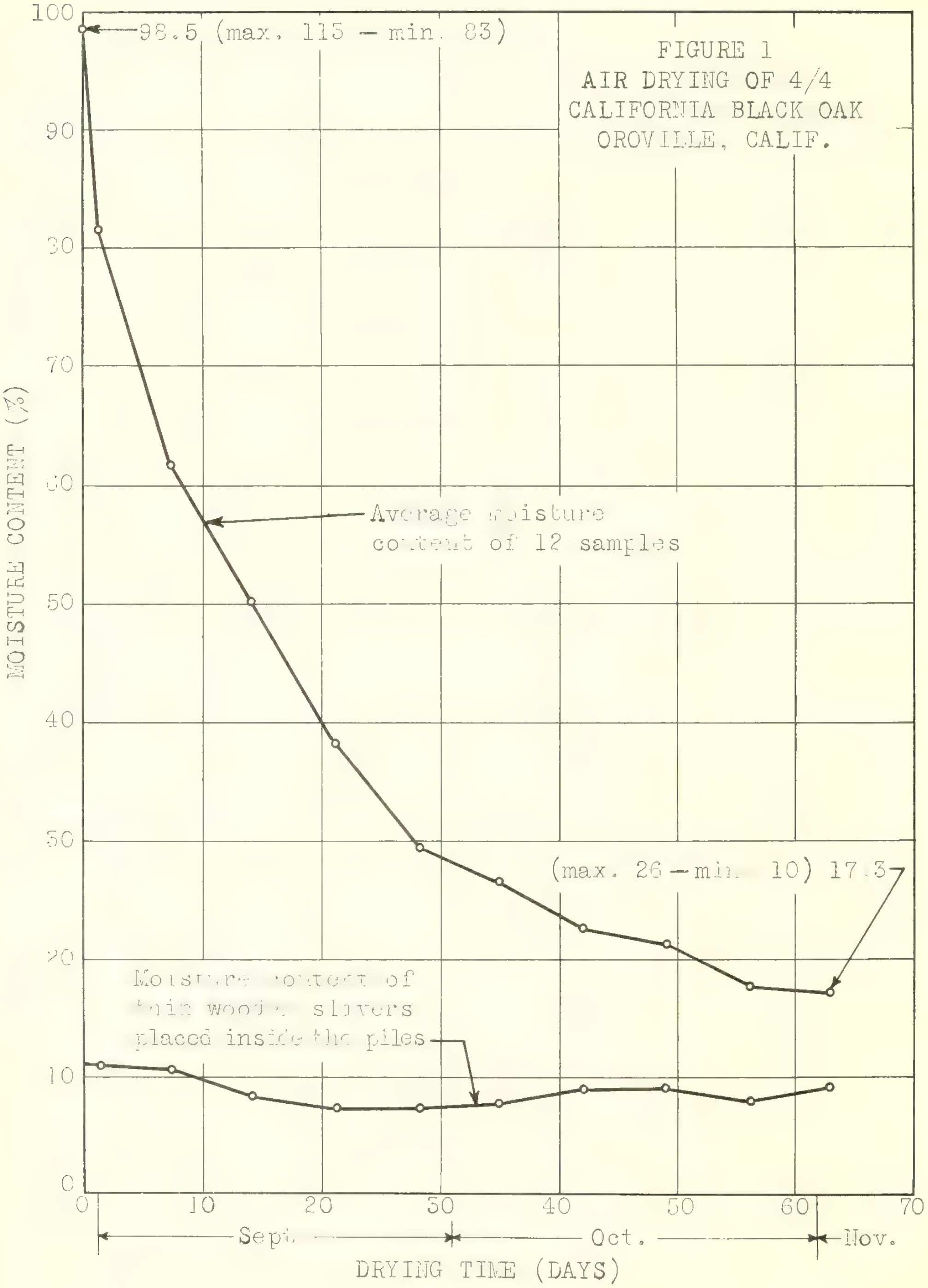


FIGURE 1
AIR DRYING OF 4/4
CALIFORNIA BLACK OAK
OROVILLE, CALIF.

Kiln Drying of Air-dried Stock

Previous experience indicated that stock which had been air dried to a moisture content of 20 percent or less could be kiln dried with relative ease. This fact was further substantiated by drying experiments in both the small experimental kiln and the larger commercial kiln.

Four-quarter, random-width stock from the air-drying yard at a moisture content of 21 percent was dried to a final moisture content of 8 percent in the small experimental kiln in $7\frac{1}{2}$ days, including one day of conditioning to remove drying stresses (fig. 2).

Drying defects in this run were negligible. There was no checking, honeycomb, or collapse, and the final range of moisture content was from 7.2 to 9.4 percent. The lumber was stress-free after the conditioning treatment.

By the time the bulk of the oak lumber was loaded into the commercial kiln, it had further air dried to a moisture content of 17.3 percent.

There was not sufficient lumber to make up a full kiln charge, so the five units of oak were dried along with units of 6/4 sugar pine, using a predetermined schedule calculated to be reasonable for both the air-dried oak and the green pine. Faster drying could no doubt be done by using a more severe schedule, and judging from the results obtained thus far in the kiln drying of previously air-dried stock, equally good results could be expected.

The results of this run in the commercial kiln were good (fig. 3). There was no loss from the usual drying defects (checks, splits, collapse, warp, etc.). The lumber was fairly stress-free after the final conditioning treatment. Some boards in this charge were mis-cut, being considerably thicker than 4/4. These thick boards naturally dried more slowly and had a higher final moisture content. In these boards the conditioning treatment did not relieve the drying stresses completely. More uniform drying and more uniform relief of stress can be expected when drying lumber that is manufactured to a more uniform thickness.

Kiln Drying Green-from-the-saw

One attempt to kiln dry a charge of this 4/4 California black oak green-from-the-saw was not successful. A reasonably mild drying schedule was used yet very poor results were obtained, indicating that in kiln drying California black oak green-from-the-saw a very mild drying schedule will be required. Such a schedule when used in a modern kiln capable of accurate control of drying conditions would no doubt produce well-dried lumber. But as the drying time would be increased, such an operation would be less attractive than a combination of air drying following by kiln drying.

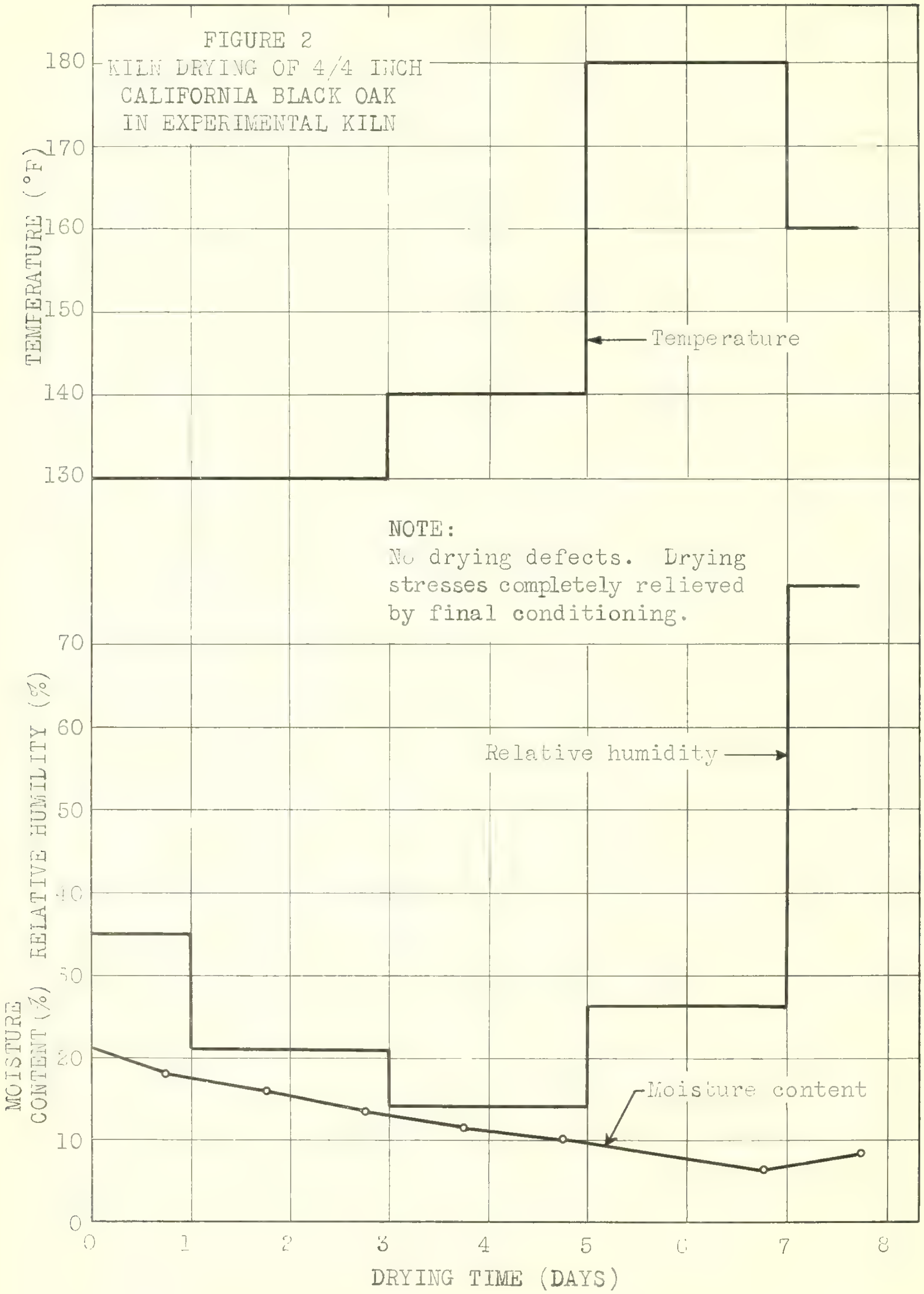


FIGURE 2
KILN DRYING OF 4/4 INCH
CALIFORNIA BLACK OAK
IN EXPERIMENTAL KILN

NOTE:
No drying defects. Drying stresses completely relieved by final conditioning.

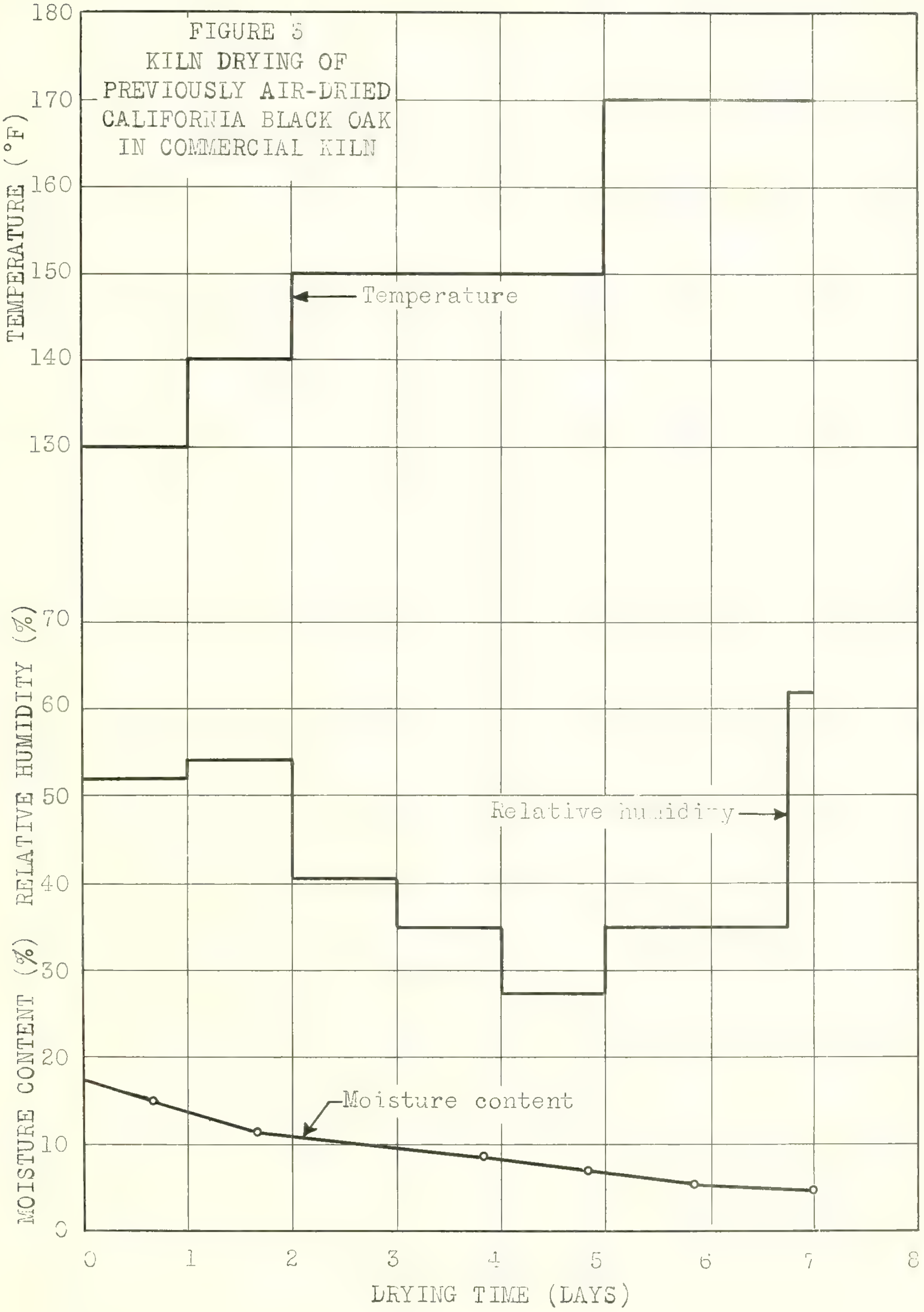


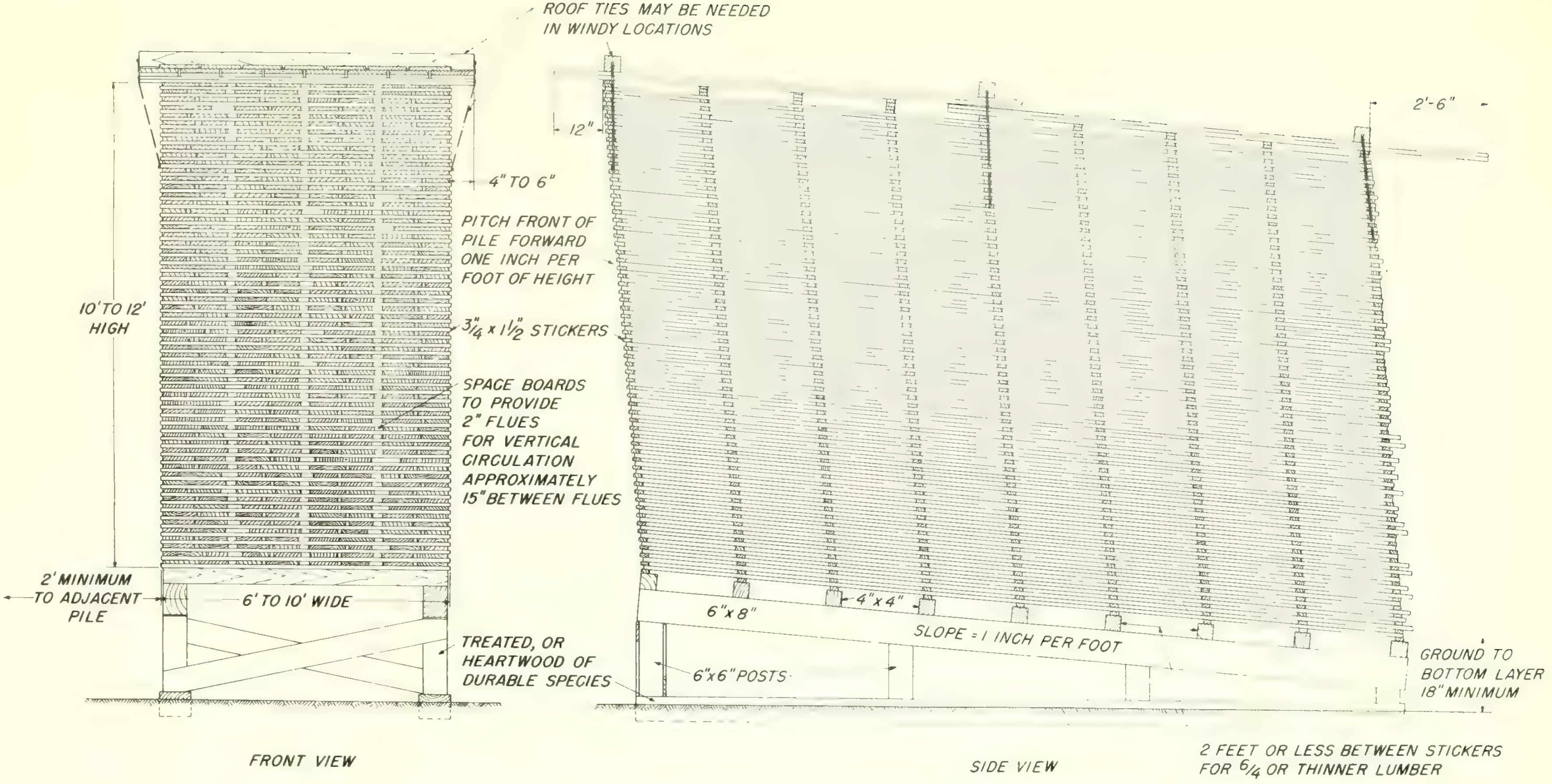
FIGURE 5
KILN DRYING OF
PREVIOUSLY AIR-DRIED
CALIFORNIA BLACK OAK
IN COMMERCIAL KILN

Drying degrade in the form of collapse and excessive warping developed during this experimental kiln run to such an extent that much of the lumber was completely spoiled. These unfavorable results indicate that the drying temperature is of considerable importance and that even the mild initial kiln temperatures (120° F) weakened the wood sufficiently to cause serious warping and collapse. Surface checking, on the other hand, was not severe, indicating that in kiln drying similar material a lower temperature schedule, with the same humidities, might be expected to produce better results.

CONCLUSION

The first experiments in the air drying and kiln drying of California black oak showed that it can be seasoned readily in the form of 3/4-inch flooring strips, 3 and 6 inches wide. Further experiments show that it can also be seasoned readily as full 1-inch thick boards up to 14 inches wide. Though thicker sizes can no doubt be seasoned successfully also, there appears to be little need to do so. There are good markets for large quantities of inch-thick oak lumber.

These experiments show that California black oak can be seasoned by well established, conventional methods, and that seasoning should not be a limiting or retarding factor in more complete utilization of this species.


ROOF TIES MAY BE NEEDED IN WINDY LOCATIONS
12"
2'-6"
4" TO 6"
PITCH FRONT OF PILE FORWARD ONE INCH PER FOOT OF HEIGHT
10' TO 12' HIGH
$3/4$ x $1\frac{1}{2}$" STICKERS
SPACE BOARDS TO PROVIDE 2" FLUES FOR VERTICAL CIRCULATION APPROXIMATELY 15" BETWEEN FLUES
2' MINIMUM TO ADJACENT PILE
6' TO 10' WIDE
TREATED, OR HEARTWOOD OF DURABLE SPECIES
6"x8"
4"x4"
SLOPE = 1 INCH PER FOOT
6"x6" POSTS
GROUND TO BOTTOM LAYER 18" MINIMUM
2 FEET OR LESS BETWEEN STICKERS FOR 6/4 OR THINNER LUMBER

FRONT VIEW

SIDE VIEW

ESSENTIAL FEATURES IN PILING FOR AIR SEASONING

INTENDED MAINLY FOR HARDWOOD LUMBER THAT IS PRONE TO CHECK
(SEE INSTRUCTIONS ON REVERSE SIDE)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN MARCH 1947

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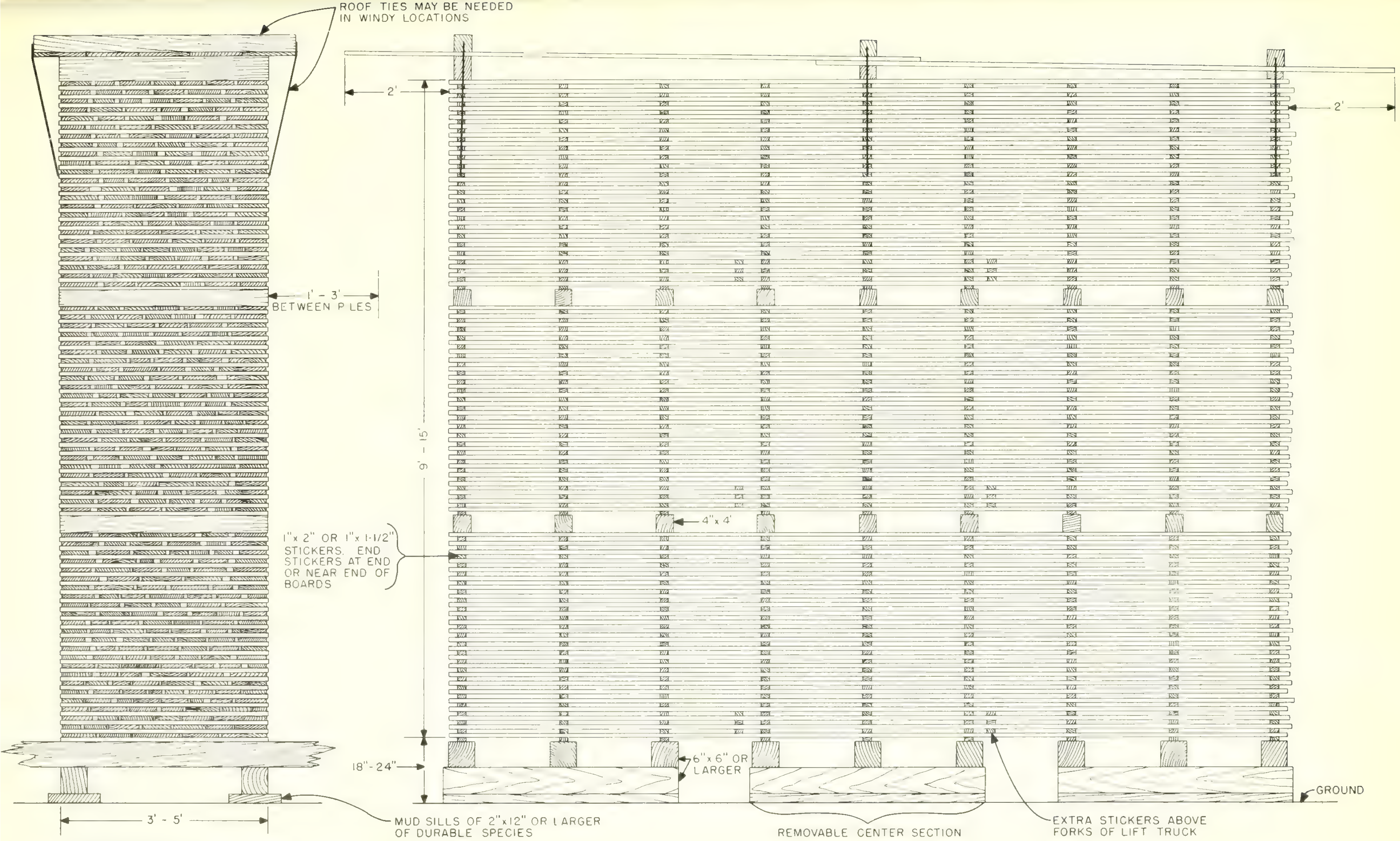
FOREST PRODUCTS LABORATORY

INSTRUCTIONS IN FLAT PILING TO TAKE CARE OF VARIATIONS IN LOCAL CONDITIONS AND IN SPECIES AND SIZES OF STOCK

To reduce the occurrence of:		
Checking	Warping	Blue stain and decay
Note: *A relatively slow initial drying rate is needed.*	Note: *Proper support and freedom from external forces are needed.*	Note: *Fast surface drying is needed or chemical treatment.*
1. Use wider piles or a double-pile on a common foundation.	1. Place stickers in exact alinement over good foundation members.	1. Reduce width of pile.
2. Use minimum space between piles (2 feet).	2. Use close spacing between stickers, such as 16 inches.	2. Increase width of flues.
3. Use minimum width of flues (1 inch).	3. Use stickers of uniform thickness.	3. Increase space between piles.
4. Pile boards edge to edge as nearly as possible in upper part of pile.	4. Avoid big variations in board thickness in any one layer.	4. Provide 6 feet or more between rear end of piles.
5. Use minimum thickness of stickers (1/2 inch).	5. Use a roof that provides good protection from sun and rain.	5. Keep yard clean and avoid blocking air space below piles.
6. Use wider projecting stickers in front and rear of pile.	6. Provide some weight on top of pile to hold down top layers.	6. Use a chemical dip (see Forest Products Laboratory Technical Note 225).
7. Use shields around pile to protect against wind, rain, and sun.	7. In drying random length lumber, avoid unprotected and unsupported overhanging ends by sorting for length or by box piling.	
8. In drying random length lumber, avoid unprotected and unsupported overhanging ends by sorting for length or by box piling.		
9. Use end coatings.		


ROOF TIES MAY BE NEEDED IN WINDY LOCATIONS
2'
2'
1' - 3' BETWEEN PILES
9' - 15'
4" x 4'
1" x 2" OR 1" x 1-1/2" STICKERS. END STICKERS AT END OR NEAR END OF BOARDS
6" x 6" OR LARGER
18"-24"
GROUND
3' - 5'
MUD SILLS OF 2" x 12" OR LARGER OF DURABLE SPECIES
REMOVABLE CENTER SECTION
EXTRA STICKERS ABOVE FORKS OF LIFT TRUCK

END VIEW OF UNIT PACKAGES

SIDE VIEW

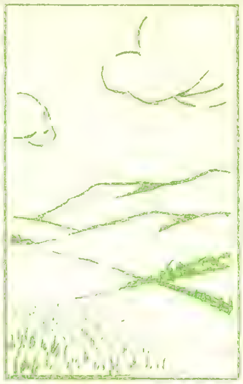
UNIT PACKAGE PILING FOR YARD DRYING

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U S DEPARTMENT OF AGRICULTURE
SEPTEMBER, 1950
A E K.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *

STEPHEN N. WYCKOFF, Director



No. 76 February 26, 1951

RELATIVE RATING OF FORAGE SPECIES FOR RESEEDING FOREST RANGES IN NORTHEASTERN CALIFORNIA

By Donald R. Cornelius, Range Conservationist[1]

"What to plant?" is usually the first question to be asked when artificial reseeding is considered for the improvement of deteriorated range. To help answer the question, forage plants have been tested by the California Forest and Range Experiment Station on the Lassen, Modoc, and Plumas National Forests since 1946. This paper gives relative ratings of 46 species, on the basis of their performance during the first 3 years of testing. Twenty of these species are native to the United States; 26 are introductions from foreign countries. Twenty of the 46 species were rated good or better for the ponderosa pine zone, but only 3 for the Great Basin sagebrush zone.

For these tests, nursery row seedings were made in each of the 3 years at different locations in the Great Basin sagebrush zone at an elevation of about 4500 feet, and in the ponderosa pine zone at elevations of 5600 to 7500 feet. In each of the zones the sites selected for seeding were depleted dry range areas dominated by sagebrush. The results are not applicable to wet meadow sites.

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[1] The author appreciates the cooperation given him by the Soil Conservation Service Nursery Division, Pacific Coast Region, for supplying a large amount of the seed used for testing; the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the University of California Agricultural Experiment Station for some seed used; and Mr. J. C. Hays and Mr. T. S. Brown, Farm Advisors of the University of California Extension Service, for suggestions regarding species to test.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

The experimental areas were not cultivated after seeding but were treated in the same way as large-scale reseeding projects, including protection from livestock grazing for at least 2 years. Each species was planted in a separate 5- by 20-feet plot. The plots were replicated twice and randomized at each of the site locations. Seedbed preparation included plowing with one-way wheatland plow in the summer to eradicate the sagebrush, and light discing in the autumn to smooth the seedbed before marking the rows for hand seeding. A six-row runner-type marker, constructed of 2- by 4-inch boards set on edge and pulled by a wheel tractor, was used for making rows about 2 inches deep and 2 inches wide. The rows were spaced 20 inches apart. In making the rows, the runners firmed the soil in the bottom of the rows--an aid in retaining soil moisture. The seed was scattered in the rows by hand and covered by a single-disc grain drill or a heavy log chain dragged across the rows.

Relative ratings from 1 (the highest) to 10 (the lowest) were made for each plot toward the end of each growing season. The first-year rating was on density of stand and vigor. Thereafter, the ratings also considered forage and seed production. The relative numerical ratings were averaged and assigned adjective ratings for use in this report.

High germination and strong seedling vigor are two very important characteristics for species used in reseeding ranges. Although some native plants are well adapted to certain sites, they might not be suitable for use in artificial revegetation if germination is low and seedlings are weak. On the other hand, it should be recognized that such ratings as these give an advantage to species which produce forage quickly. Species that develop slowly and persist over a long period of time may give the highest average yield of forage, but are at a disadvantage when evaluated at the end of 3 years.

A better appraisal of the more promising species will be made after another 2 years. Larger plots now under study will also strengthen the evaluation. Then too, strains of the better species have been obtained from plant breeders or selected from native grasslands and are now under test in range plots. Therefore, the ratings given in the accompanying table may be refined. The present list, however, should prove helpful to range managers wanting to know what species to seed; it represents the best evaluation available from performance in the nursery rows.

(First of 2 pages)

ADAPTABILITY OF FORAGE SPECIES
for
Reseeding Ranges in Ponderosa Pine and in
Great Basin Sagebrush Zones of Northeastern California

Species	Ponderosa pine zone	Great Basin sagebrush zone	Native (N) or Introduced (I)
Grasses			
Agropyron cristatum	Good	Good	I
" dasystachyum		Medium	N
" elongatum	Good	Medium	I
" inerme		Good	N
" intermedium	Good	Excellent	I
" riparium	Good	Medium	N
" smithii	Poor	Poor	N
" spicatum	Good		N
" trachycaulum	Good	Medium	N
" trichophorum	Good		I
Agrostis alba	Poor	Failure	I
" alba tenuis	Medium		I
Alopecurus pratensis	Good		I
Arrhenatherum elatius	Poor	Failure	I
Bromus erectus		Poor	I
" inermis	Good	Poor	I
" marginatus	Medium	Poor	N
Dactylis glomerata	Good	Poor	I
Elymus canadensis	Good	Medium	N
" glaucus	Medium	Poor	N
" junceus	Poor	Poor	I
" triticoides	Medium		N
Festuca arundinacea	Good	Failure	I
" idahoensis	Poor	Poor	N
" ovina	Medium		I
" rubra commutata	Medium	Poor	I
Hordeum bulbosum	Medium	Failure	I
Lolium perenne	Medium		I
Oryzopsis hymenoides		Failure	N
Phalaris arundinacea	Medium		N
Phleum pratense	Good	Failure	I
Poa ampla	Good	Medium	N
" nevadensis	Good	Failure	N
Stipa lemmoni		Medium	N

(Second of 2 pages)

ADAPTABILITY OF FORAGE SPECIES
for
Reseeding Ranges in Ponderosa Pine and in
Great Basin Sagebrush Zones of Northeastern California (Cont.)

Species	Ponderosa pine zone	Great Basin sagebrush zone	Native (N) or Introduced (I)
Legumes			
Astragalus cicer	Good		I
" falcatus	Medium		I
Lotus americanus	Poor	Failure	N
" corniculatus	Good		I
" uliginosus	Good		I
Lupinus calcaratus	Good	Poor	N
Medicago sativa-falcata	Poor	Medium	I
Melilotus officinalis	Good		I
Trifolium hybridum	Poor	Failure	I
" involucratum	Medium		N
" repens latum	Poor	Failure	I
Browse			
Purshia tridentata	Poor	Failure	N

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 77 March 15, 1951

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UNIT AREA CONTROL IN CALIFORNIA FORESTS

By William E. Hallin, Forester

"Unit Area Control"--A new term is heard by California foresters. It is based upon research by the California Forest and Range Experiment Station. Its application in the region is believed to offer the most realistic approach to sustained yield forestry. This article outlines the silvicultural basis of unit area control and some of the pertinent points in its application.

Unit area control is a silvicultural concept in which the essential characteristic is "detailed control of stocking on small areas." The basic idea is not new. In some localities it has been referred to as forestry by the acre. Duncan Dunning[1] selected the term to name the concept when he developed its application to California forests.

"Unit area" and "control"--the two parts of the term--are the keys to understanding this concept. "Unit area" was selected because silviculture must fit stand conditions that are natural units. Forest stands normally break down into homogeneous stand units, or unit areas, varying in size from a fraction of an acre to many acres. Characteristics commonly determining the homogeneity of these unit areas are: Age class, species composition, stocking, and presence or absence of seed trees.

"Control" was selected because it most aptly describes the aim of the silvicultural treatments applied to the unit areas. Control of the ground by a desirable or valuable tree species rather than by brush or inferior tree species is of first importance. Also, control means continuously maintaining adequate stocking of a desirable species growing at a rate commensurate with the site. Silvicultural treatments applied at the proper time are the means by which the forester controls the stand.

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[1] Formerly Division Chief, Division of Forest Management Research, California Forest and Range Experiment Station, now retired.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Unit area control is in sharp contrast to the widely used forms of tree selection. Silviculture is applied according to the needs and condition of each unit area of the stand rather than tree by tree according to generalized rules. A tree selection system of cutting may, however, be appropriate for some unit areas of some species, for example, in an all-age condition class of the tolerant white fir.

There is a definite distinction between the basic concept of unit area control and the specific techniques or treatments used for specific units. Unit area control as a term was first used in connection with a cutting trial in the sugar pine-fir type; consequently, many foresters think the term refers merely to the technique used in sugar pine management. This is not the case. Applying silviculture by unit areas is appropriate and desirable for other major types as well. So far, however, techniques have been developed only for pine and mixed-conifer types in the Sierra Nevada. The remainder of this discussion is concerned with these types.

Basis of Unit Area Control

Thirty years of research in the ponderosa pine and mixed conifer forests of the Sierra Nevada have shown that previous methods of silviculture were not providing adequate restocking of pine. Analysis of records indicated a new approach was necessary. From this work, procedures that gave most promise of success were formulated by Duncan Dunning. These procedures are techniques for applying unit area control in the ponderosa pine and mixed-conifer forests. Large-scale trial and demonstration of these applications are under way in ponderosa pine at the Blacks Mountain Experimental Forest and in sugar pine-fir at the Stanislaus Experimental Forest. At both places small-scale studies are being carried on to implement and improve the application of unit area control.

In managing forest stands procedures to be followed depend on (1) objectives of the land manager, (2) silvical characteristics of the species, (3) condition of the stand when treatment starts, and (4) treatment required to obtain the desired results.

Objectives of Management

What the land manager wants is the first controlling factor in determining what is done to the forest. The land manager must decide the species desired, the acceptable degree of stocking, the size and kind of product desired, and make the other customary managerial decisions.

In the ponderosa pine and mixed-conifer types a primary objective of land managers is to grow large size sugar or ponderosa pine peeler logs or sawlogs. If sustained production with a growth rate commensurate with the site capacity is desired, conversion of the unmanaged stand to a regulated stand--a forest with each age class through rotation or harvesting age, uniformly represented and adequately stocked--is an essential objective.

Silvical Characteristics

Some of the important silvical characteristics of sugar and ponderosa pine that affect their management are: (1) They are intolerant species and grow best in even-aged groups. (2) They prefer bare mineral soil for germination. (3) If pine starts free of competition, its initial growth is rapid and usually it is able to compete successfully with fir, brush, and other vegetation that may subsequently become established. (4) For best growth, thinnings and cleanings are usually necessary. (5) California ponderosa and sugar pine do not readily establish themselves under brush and white fir. (6) Where they have become established under brush or white fir they do not develop properly unless released from this competition. (7) Pine seeds are the preferred food of numerous rodents commonly found in our forests. (8) Pine does not prune itself of branches naturally during practical rotation periods.

Site quality, through its effect on growth rates, has an important effect on acceptable stocking, length of rotations, and final yield.

Condition of the Stand--Condition Classes

Ponderosa pine and sugar pine stands when considered by large areas are all-aged; however, when the forest is examined closely the trees are seen to occur in even-aged groups, usually small in size and homogeneous in respect to stocking, species, etc. Dunning has called these groups condition classes.

The objects of a classification by condition classes are: (1) To subdivide the forest or working circle into natural unit areas sufficiently small and homogeneous for practical, uniform treatments (harvest cutting, regeneration, stand improvement, etc.). (2) To determine (a) which unit areas have existing stands adequate to carry as growing stock and, if they do, whether or not they should be subjected to an improvement cut, and (b) which unit areas have stands that should be clear cut and the unit regenerated. (3) To provide the basis for the cutting plan, cutting budgets, allowable cut, and other treatments for a working plan most likely to accomplish stand regulation in the conversion period.

The basis for a condition classification is the naturally occurring group stand structure. Dominant trees are used as indicators in condition classification because they make up over 80 percent of the stand in board-foot volume but only about 40 percent of the stand in numbers of trees. The criteria for recognizing and classifying condition classes are age, species, degree of stocking relative to the stand aimed for in regulation, and--for unit areas needing regeneration--the presence or absence of seed trees and the presence or absence of brush needing eradication.

The age classes commonly used for the overstory are: (1) Old--300 years plus--tree Class 5 in Dunning's tree classification system; (2) mature--150 to 300 years--tree Class 3; (3) immature--75 to 150 years--tree Class 1. The age or size classes commonly used for the understory are: (1) Poles--4 to 12 inches d.b.h.; (2) seedlings and saplings--trees under 4 inches d.b.h.

The species to which the unit area is to be primarily designated is based on the relative number of dominants. If a third or more of the dominants are sugar pine, the species for the unit is designated as sugar pine. If a third or more of the dominants are ponderosa pine but less than a third sugar pine the species for the unit is designated ponderosa pine, and so on down the list of species in the order of their desirability. Although this species designation is for the purpose of classifying the unit areas at the time of inventory or treatment, it commonly indicates the species to be favored on the particular unit area for the conversion period. With favorable conditions, however, the forester will treat some unit areas so as to change the species to more valuable ones.

Stocking is rated as adequate or inadequate on the basis of a minimum stocking that is acceptable to the land manager. On experimental forests in the better sites a minimum stocking of 50 percent of site capacity has been used.

Seed trees are rated as adequate or inadequate for old or mature unit areas without adequate advance growth. Seed trees should be around the border of the unit area to be regenerated. The number and size required varies with the species.

Brush requiring eradication is rated as present or absent on unit areas needing regeneration.

Recognition of condition classes is not unduly complicated when it is viewed in terms of these few criteria. For any specific unit area the following questions should be answered: (1) What is the age class of the overstory? (2) What is the species composition? (3) For immature and mature age classes, is the stocking acceptable to carry as a reserve? (4) Is there an understory present? (5) What is the species composition of the understory? (6) Is the stocking of the understory adequate? (7) If the understory is inadequately stocked or absent, are there adequate seed trees? (8) If the understory is inadequate or absent, is brush needing eradication present or absent?

Unit areas of the different condition classes vary in size from a fraction of an acre to several acres in size. On 200 acres used in the cutting trial of sugar pine-fir on the Stanislaus Experimental Forest, the average size of condition-class units was approximately 3/4 of an acre. Figure 1, at the end of this report, is a map of 6 acres of this area. It shows some of the commonly found classes and the typical variation in size. Figure 2 shows a typical profile of the stand.

Treatments

In the application of unit area control, each unit area of a specific condition class is given its appropriate cutting and all other necessary treatments at the proper time. The immediate objective is to keep control of the ground with trees. As previously mentioned, the long-time objective is to convert the forest into a regulated stand having each age class through rotation age uniformly represented with adequate stocking and proper growing conditions. The main initial treatments to be applied are as follows:

Cutting for natural restocking is carried on in unit areas of old-age condition classes with inadequate advance growth, with suitable seed trees present, and during a year of a good seed crop. These condition class units are clear cut, but seed trees are left around the border of each unit. Rodents are controlled with lethal bait. Brush is piled and burned. Competing vegetation is eradicated, and the bare mineral soil exposed as a seedbed. If natural regeneration fails the unit area is planted at once before brush and other vegetation invades it.

Cutting for artificial restocking is carried out in the unit areas of old-age condition classes with inadequate advance growth, but with suitable seed trees absent or no seed crop in sight. These condition classes are clear cut. Slash is piled and burned. Competing vegetation is eradicated. The areas are then planted. Because of the infrequency of good seed crops a high proportion of the old condition classes may need to be regenerated by artificial means.

Timing is especially important in securing either natural or artificial reproduction. Once an area has been prepared for reproduction, it should be restocked at once, otherwise brush and other competing vegetation will invade and rapidly take control of the ground. Hence, it is vital that planting stock be available when regeneration cuts are planned, either for planting the entire area or for fill-in planting where natural reproduction fails.

Cutting for release is carried on in unit areas of old-age condition classes with adequate advance growth. The overstory is clear cut to release young growth; cutting is followed up with pruning, thinning, and other stand improvement measures.

Improvement cuts are made in young but merchantable stands (immature and mature age classes). The occasional old, malformed, or defective trees are removed to improve the condition of the stand.

On areas dedicated to sugar pine management ribes eradication also is essential.

The treatments applied to some typical condition classes are shown in Figures 1 and 2.

Application of Unit Area Control

In applying unit area control a detailed inventory and an adequate management plan are highly desirable, just as for any type of silvicultural method. The inventory can be made on a sampling basis as for other methods. A map is not essential. Areas of condition classes can be sampled by line transects, and volumes sampled with small plots. Unit area control treatments, like tree selection, can be applied even though an inventory and adequate plan are lacking. Each condition-class unit can be marked for cutting as it is reached. But an inventory and a management plan cannot be deferred if proper progression towards a regulated stand is to be accomplished.

Calculating the allowable cut and preparing the cutting plan are simplified with an inventory by condition classes. The deficiencies or excesses in the different age classes are readily shown. The condition classes can be sorted out into their proper place in the cutting plan in order to provide for a sustained cut and progression toward a regulated stand. Because the condition classes are usually even-aged, conventional yield tables can be used for growth prediction.

Short cutting cycles are desirable in order to maintain proper control of the stand. In converting virgin old-growth stands to a regulated stand, the large volume of overmature trees may complicate the task of keeping the first cutting cycle relatively short. In applying unit area control the length of the first cutting cycle can be kept short by deferring the cutting of some of the more-thrifty or less-decadent unit areas of old-age condition classes. It should be remembered, though, that when release or regeneration cuts of old-age condition classes are deferred, it generally will be desirable to remove the few trees that obviously would not survive until the next cut.

The problems of logging are no different than in other systems of cutting. Logs must be efficiently moved to the landing and advance growth and reserve trees must be protected from excessive logging damage. Advance plans for sale areas or cutting units are desirable for both silvicultural and logging considerations with any system of cutting. The desirability, while no greater, is more obvious for unit area control, in which a variety of treatments must be integrated.

Conclusion

Unit area control, developed by Duncan Dunning for application to California forests, is believed to give the most promise for successful management of these forests. It is a dynamic, growing process: as present trials are continued and new trials of it started, techniques and procedures will be modified and improved upon. Stripped to essentials, unit area control is, with due consideration of the silvical characteristics of trees, the common sense application of silviculture to the naturally occurring unit areas of the forest stand.

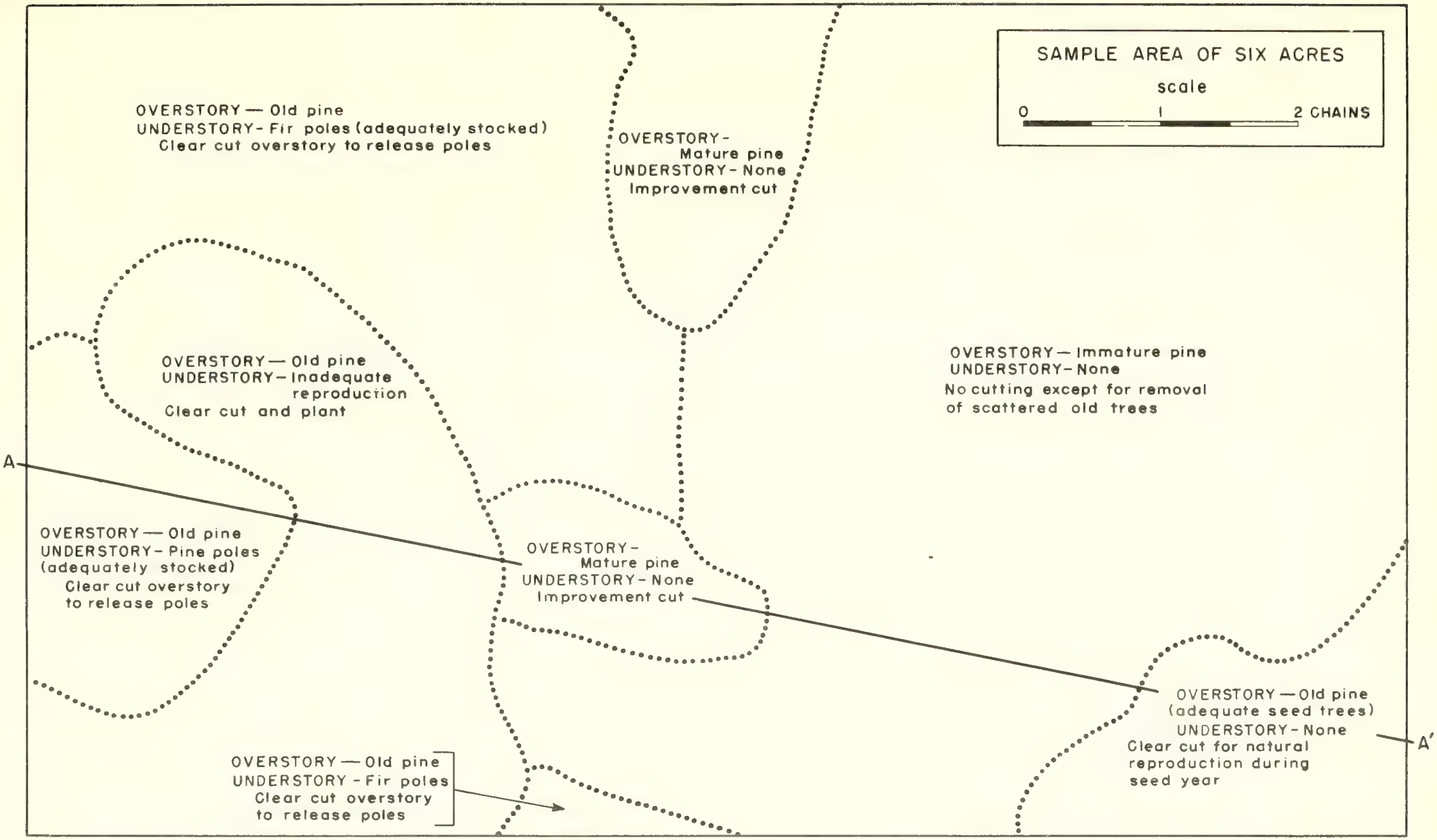
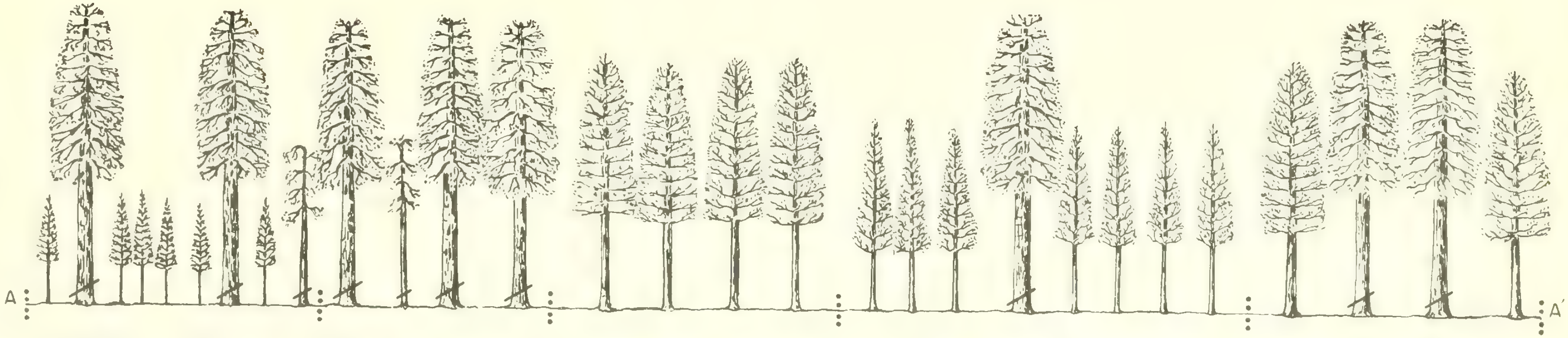

SAMPLE AREA OF SIX ACRES
scale
0
1
2 CHAINS
OVERSTORY — Old pine
UNDERSTORY- Fir poles (adequately stocked)
Clear cut overstory to release poles
OVERSTORY- Mature pine
UNDERSTORY- None
Improvement cut
OVERSTORY — Old pine
UNDERSTORY- Inadequate reproduction
Clear cut and plant
OVERSTORY— Immature pine
UNDERSTORY- None
No cutting except for removal of scattered old trees
A
OVERSTORY — Old pine
UNDERSTORY- Pine poles (adequately stocked)
Clear cut overstory to release poles
OVERSTORY- Mature pine
UNDERSTORY- None
Improvement cut
OVERSTORY — Old pine (adequate seed trees)
UNDERSTORY- None
Clear cut for natural reproduction during seed year
A′
OVERSTORY — Old pine
UNDERSTORY - Fir poles
Clear cut overstory to release poles

Figure 1 - Condition classes and first treatment on a portion of Stanislaus Experimental Forest.



OVERSTORY — Old pine

UNDERSTORY - Pine poles

TREATMENT — Group release cut, prune crop trees.

OVERSTORY — Old pine

UNDERSTORY - Inadequate reproduction

TREATMENT — Clear cut, dispose of slash, eradicate brush, plant

OVERSTORY — Mature pine

UNDERSTORY - None

TREATMENT — Where present remove occasional old or malformed or defective trees to improve stand condition.

OVERSTORY — Immature pine

UNDERSTORY - None

TREATMENT — Cut scattered old trees.

OVERSTORY — Old pine

UNDERSTORY - None

TREATMENT — Clear cut for natural reproduction during seed year, leave seed trees around border, poison rodents, pile slash, eradicate brush, expose mineral soil.

Figure 2 - Profile of stand along line A—A′, figure 1.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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RECENT DIRECT SEEDING TRIALS IN THE PINE REGION OF CALIFORNIA

By H. A. Fowells and G. H. Schubert

Direct seeding is a highly desirable method of regeneration. It is more economical and more flexible in both time and place than the planting of trees. In California, however, direct seeding generally has been an ineffective method of regeneration. Early trials by the Forest Service[1] with broadcast sowing and spot sowing invariably failed to produce an adequate stand of reproduction, primarily because forest rodents destroyed the seed or seedlings. Poisoning and trapping had little effect. Protecting seed spots with screens was judged to be effective but not economical. More recently, direct seeding, both broadcast and spot sowing, has been tried on large burns in a gamble to increase the area reforested beyond that possible by planting. Only rarely was the gamble successful and the circumstances attending the success are not known.

Nevertheless, interest in direct seeding has not diminished. A number of experiments, large and small, have been conducted in the hope that some device, procedure, or condition might be found to make the practice more successful. Many of these experiments were concerned directly or indirectly with the problem of controlling rodents, the primary obstacle to direct seeding. Others were concerned with seedbed condition and with seed treatment. In some tests the relative effectiveness of direct seeding and of planting was compared. All these experiments were tests of spot sowing, not broadcast sowing. This report summarizes these trials for those persons interested in direct seeding as a practical means of regeneration and for those interested in a background for trials of their own.

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[1] Show, S. B. 1930. Forest nursery and planting practice in the California pine region. U.S.D.A. Circular 92, 75 pp.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Agriculture--Berkeley

Trials of Controlling Rodents

The depredations of rodents may be prevented by several means: (1) Reducing or removing the rodent populations, (2) making the seed unattractive to rodents, and (3) mechanically protecting the seed from rodents.

Broadcast Poisoning

One of the common procedures for reducing the rodent populations is to distribute poison baits on the area to be regenerated and on a surrounding buffer strip before the seed is sown. Measured in terms of the success of the seeding, the effectiveness of this procedure has been variable. In the northern Rocky Mountain region Schopmeyer[2] and Helmers concluded that broadcast poisoning with thallium-treated sunflower seeds a week before seeding gave good rodent control. Results in some other regions have not been so promising.[3] Two tests in the California region did not result in satisfactory rodent control.

One of these tests was part of a natural regeneration experiment on the Stanislaus Experimental Forest in 1948. The poison bait used was oat groats treated at the rate of 3 ounces of "1080" (sodium fluoroacetate) per 100 pounds of groats. This bait was distributed in July on about 600 acres at the rate of 1/2 to 2/3 pounds per acre. To measure the effectiveness of the rodent control, 400 screened and 400 unscreened seed spots, each with 5 seeds per spot, were put out in the fall of 1948. In September 1949, 38 percent of the screened spots and 16.5 percent of the unscreened spots had one or more seedlings per spot. Many of the unscreened spots and some of the screened spots were disturbed by rodents.

From rodent trapping data[4] in the test it appears that the rodent population was temporarily reduced but built up during the fall and winter. In late September 1948, before seedfall, only one chipmunk (Eutamias sp.) was caught in 120 trap nights. In June 1949, 35 acres of the area being regenerated was treated with 5 pounds of poisoned sugar pine seed. Each seed carried about 12 milligrams of "1080", an extremely toxic dosage. Two weeks after this second baiting 8 mice (Peromyscus sp.) and 1 chipmunk were caught in 200 trap nights.

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[2] Schopmeyer, C. S. and A. E. Helmers. 1947. Seeding as a means of reforestation in the northern Rocky Mountain region. U.S.D.A. Circular 772, 31 pp. illus.

[3] Huberman, M. A. 1940. Experimental direct seeding by the Forest Service. Issued by Division of Forest Management Research, U. S. Forest Service, Washington, D. C. 57 pp. processed.

[4] These observations were made in cooperation with Joseph Keyes, U. S. Fish and Wildlife Service, and Dr. E. W. Jameson, University of California.

The other test was made in the Stanislaus National Forest in 1934. Preparatory to a planting and seeding trial, the area to be seeded and a surrounding buffer strip were treated with grain carrying strychnine. First-year establishment of seedlings indicates that the rodent control measures were not sufficiently effective. The percent of seed spots with one or more seedlings was:

Species	Spots screened	Spots unscreened
Ponderosa pine	51	6
Sugar pine	58	6
White fir	8	2

Burning

Burning often has been suggested as a means of reducing the rodent population. Although burning with only this objective has not been tried, two seed-spotting trials in burns indicate the possible results. A very hot fire occurred in Anderson Valley on the Stanislaus National Forest in late July 1934. That fall a group of screened and unscreened seed spots were put in the burn. Although better germination and survival occurred on the screened spots (table 1), regeneration would have been possible without the screen protection. The rather high germination and survival rate in the unscreened spots indicates a small amount of disturbance by rodents. It is not known whether the light disturbance resulted from a reduced population of rodents or from the heavy seed crop present on trees surviving the fire--more than enough seed to satisfy the appetite of a normal rodent population.

Table 1.--Germination and first-year survival of screened and unscreened seed spots in Anderson Valley, 1935

Species	Protection	Number spots	Germination	Survival
			Percent[1]	Percent[1]
Ponderosa pine	none	1660	83	67
	screens	340	91	83
Sugar pine	none	160	59	44
	screens	40	85	78
Jeffrey pine	none	160	82	75
	screens	40	98	90
White fir	none	160	81	59
	screens	40	95	88

[1] Percent of seed spots with one or more seedlings.

On the other hand fire apparently had little effect on rodents in a brushfield planting trial at Burney Springs, Lassen National Forest, in 1936. In the fall after the burn, 250 screened and 250 unscreened spots, with 10 - 15 seed per spot, of each of ponderosa pine and Jeffrey pine were set out. Germination and first-year survival of the unscreened spots was relatively low compared to the screened spots (table 2).

Table 2.--Germination and survival in screened and unscreened seed spots sown at Burney Springs, 1936

Species	Germination		Survival	
	Screened	Unscreened	Screened	Unscreened
	Percent[1]		Percent[1]	
Ponderosa pine	69	31	59	15
Jeffrey pine	86	16	79	10

[1] Percent of seed spots with one or more seedlings.

Repellants

Attempts to prevent rodent damage by using materials supposedly possessing repellant qualities have been accompanied with varying success.[5] Toxic agents have been advocated as possible repellants on the hypothesis that if a rodent obtained a sub-lethal dose, it might subsequently avoid the seed. This conjecture has not been supported by seeding trials.

In the Big Springs plantation on the Lassen National Forest in 1935, 500 seed spots of ponderosa pine and of Jeffrey pine were set out with each of these treatments: (1) Seed not coated, spots not screened; (2) seed coated with a mixture containing strychnine, spots not screened; and (3) seeds coated and spots protected. Germination in the unscreened seed spots, with seed coated or uncoated, was less than 1 percent. Germination in the screened seed spots, with seeds coated was: ponderosa pine 39 percent, Jeffrey pine 42 percent.

In a seeding trial at Burgess Springs, Lassen National Forest, in October 1935, ponderosa and Jeffrey pine seed was planted with a corn planter at the rate 1 to 3 seeds per spot. The seeds were coated with a mixture of strychnine, plaster of Paris, and gum arabic. Seedlings were found in 9.3 percent of the ponderosa spots, about 29,000 in number, and 9.8 percent of a like number of Jeffrey pine spots. A germination test of the seeds so coated showed rates of 50 percent and 68 percent, respectively.

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[5] Huberman, M. A. op. cit.

In the spring of 1950, on the Stanislaus Experimental Forest, stratified sugar pine seed was coated with "1080" carried in a latex base and rolled in precipitated chalk. Five coated seeds were sown in each of 240 unscreened spots. Five untreated seeds were sown in each of 240 unscreened spots and 240 screened spots. Seedlings germinated in 4 percent of the treated, unscreened spots, 10 percent of the untreated, unscreened, and 80 percent of the untreated, screened spots. Either the rodents did not ingest sufficient toxic material from the seed coats or the rodent population was large enough that rodent losses did not affect the extent of the depredations. Coating of the seed did not affect germination, according to a greenhouse test in which 64 percent of the coated seed and 65 percent of the uncoated seed germinated.

Pelleted Seed

Two small trials were made with ponderosa pine seed enclosed in a commercial pellet material containing a supposed rodent repellant. In one test no seed germinated out of several hundred seed planted in an old cut-over area. In the other test no seed germinated in 20 spots with 5 pelleted seed per spot while seedlings were found in 65 percent of another 20 spots of pelleted seed protected by screens.

Mechanical Protection

From the foregoing discussion it is obvious that, except in the Anderson Valley trial, success in seed spotting was obtained only when the spots were protected by screens. Germination and survival in the screened spots was consistently higher than that in the unscreened spots, regardless of the treatment of the latter.

Seedbed Conditions

Mineral soil or the ash-covered surfaces following fire appear about equally good as receptive surfaces for direct seeding. In a test of site preparation at Burney Springs in the spring of 1937, 900 seed spots of ponderosa pine and of Jeffrey pine were set out in each of these conditions: (1) Stripped brush, (2) burned brush, and (3) burned and stripped brush. Stratified seed was sown in these screened spots. The seedbed condition, either mineral soil, ash, or a mixture, had no appreciable effect on the germination, judging from the percent of seed spots in which one or more seedlings germinated:

Seedbed conditions	Ponderosa pine	Jeffrey pine
	- - - Percent	- - -
Stripped	92	95
Burned	89	92
Burned and stripped	91	91

Survival (one or more seedlings per spot) of the two species combined, at the end of the second year, was 75, 81, and 84 percent for the stripped, burned, and burned and stripped, respectively. Inasmuch as competition as well as surface condition may have affected survival, the differences in survival cannot be ascribed to surface condition.

In a 1940 test of seed spotting on mineral soil and on conifer and brush litter, germination, based on the total number of seedlings found, was as follows:

Species	Mineral soil	Litter
	- - - Percent	- - -
Ponderosa pine	53	28
Sugar pine	70	54
Incense cedar	32	21
White fir	21	18

There were 120 seed spots, with 15 seed each, of each species in each seedbed condition. The difference in rate of germination between conditions is statistically significant. Seedbed condition had little effect on the germination rate of white fir, as indicated by a statistically significant species-treatment interaction.

The first-year survival of sugar pine seed spots on large burned slash piles with a heavy ash layer was 53 percent (one or more seedlings per spot), compared to 59 percent on adjacent mineral soil. These observations were made on the Stanislaus Experimental Forest in 1950.

Seed Treatment

Sowing seed in spring may reduce rodent damage because the period of exposure of the seed to rodents is shortened appreciably. However, sugar pine seed must be stratified if sown in the spring. Ponderosa and Jeffrey pine germinate more promptly if stratified prior to spring sowing. Although direct comparisons of the use of stratified and unstratified seed have not been made, some of the results of seeding with stratified seed may be of interest. In the Burney Springs experiment 5,400 screened seed spots were sown in the spring of 1937 with stratified ponderosa and Jeffrey pine seed. Seedlings were found in 92 percent of the spots. In the same plantation seedlings germinated in 77 percent of 500 screened spots sown in the fall of 1936 and in 81 percent of 5,400 screened spots sown in the fall of 1937. The seed in these fall-sown spots was not stratified prior to sowing.

In the spring of 1950, stratified sugar pine seed was sown in 946 screened spots on the Stanislaus Experimental Forest. At the end of the first year 76 percent of the spots had one or more surviving seedlings.

During the stratification process, seed often becomes moldy. In an effort to prevent the development of the mold[6] and perhaps increase germination, sugar pine seed was dusted with an organic mercury fungicide prior to stratification. The treatment had no effect on germination. Seedlings were found in 55 percent of the spots with treated seed and in 58 percent of the spots with untreated seed. Either the fungicide was not effective or the specific unidentified molds were not pathogenic to sugar pine seed.

Relative Effectiveness of Seeding and Planting

Seed spotting has been about as effective as planting when the seed spots were protected from rodents, judging from second-year survival in several tests (table 3). In the spring 1937 test at the Burney Springs brushfield plantation, survival of ponderosa and Jeffrey pine screened seed spots was practically as high as the survival of the planted stock (1-1 ponderosa and Jeffrey pine). Survival of both seed spots and planted trees was very low in the fall test in the same plantation, but seed-spot survival was equal to that of planted stock. Survival of screened spots in the Anderson burn was as good as that of planted stock. Even unscreened spots had satisfactory survival in this burn where rodent damage had been low. In a test in the Stanislaus Experimental Forest in 1934, screened seed spots of ponderosa pine were as effective as planted stock. The survival of sugar pine spots was more than five times greater than the survival of the planted sugar pine stock. In a test in 1941 the proportion of screened seed spots of sugar pine with one or more seedling was a little higher than the survival percent of planted 1-1 sugar pine stock.

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[6] Schubert has observed that infection of seed with Cylindrocarpon sp. caused poorer germination. Schubert, G. H. 1950. Viability losses of sugar pine (Pinus lambertiana, Dougl.) seed infected with certain fungi. M.S. thesis filed in the library of the University of California.

Table 3.--Second-year survival of seed spots and planted stock in certain tests where comparisons are possible

Location, year, and species	Seed spots		Planted stock	Basis
	Screened	Unscreened		
	- - - Percent	- - -	Percent	
Burney Springs, 1937, spring; Ponderosa and Jeffrey pine	80	-	86	5,400 seed spots 5,400 planted trees
Burney Springs, 1937, fall; Ponderosa and Jeffrey pine	15	-	15	5,400 seed spots 5,400 planted trees
Stanislaus, 1934;				
Ponderosa pine	43	5	44	2,725 seed spots
Sugar pine	46	3	8	2,975 planted trees
Anderson burn, 1934; Ponderosa pine	76	64	74	2,000 seed spots 2,400 planted trees
Stanislaus, 1941; Sugar pine	50	-	41	592 seed spots 592 planted trees

Summary and Discussion

In a series of seed-spotting tests conducted over a period of years, depredations of forest rodents were the chief obstacle to successful direct seeding. Screening of the seed spots was the only consistently effective means of protecting the seed from rodents. At present, the high cost of fabrication and use of the conical screens used in the tests prohibits their general adoption. The dome-shaped screens designed and found successful by Keyes and Smith[7] are much cheaper to produce but must be removed no later than the second year. Currently an inexpensive, expendable screen,[8] which may not need to be removed, is being tested extensively in the hope that this screen will make direct seeding feasible. A current study of the habits of forest rodents by biologists of the University of California may yield clues leading to more effective use of poisons or repellants. Until the problem of protecting seed from rodents is solved, direct seeding cannot be recommended as a practical means of regeneration.

Given adequate rodent protection, however, seed spotting was found to be a satisfactory method of regeneration, compared to planting, on burned surfaces and on mineral surfaces with fall-sown seed or spring-sown stratified seed.

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[7] Keyes, Joseph and C. F. Smith. 1943. Pine seed-spot protection with screens in California. Jour. Forestry 41: 259-264.

[8] Designed by Mr. Joseph Keyes.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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(Revised October 1953)1/

THE UNIVERSITY [illegible]
SEWANEE, TENN.

PRODUCTION OF LOGS AND BOLTS FOR PLYWOOD, PULP, CONTAINER VENEER, SHINGLES, COOPERAGE, POLES, AND PILING IN CALIFORNIA, 1950

By

Richard H. May, Forester
Division of Forest Economics

Early in 1951, as part of a nation-wide survey requested by the National Production Authority, the California Forest and Range Experiment Station made a survey of the equipment, supplies, and manpower requirements of the wood-using industries in California. Supplementary to this survey, data were obtained on the 1950 production of logs and bolts for pulp, container veneer, shingles and sawed shakes, cooperage, and poles and piling. These production data have considerable value as independent statistics and are here presented for the information of interested individuals and agencies.

Since only fragmentary information on production of the plywood industry was obtained in the equipment-manpower survey, the plywood log production figures included here were estimated from statistics on peeler log consumption and stocks supplied by the Bureau of the Census, U. S. Department of Commerce, and from other data of local origin.

Sawlog production was not surveyed by the Station because similar information on lumber production is collected and published annually by the Bureau of the Census. Census figures for 1950 show a total lumber production for California and Nevada of 4,263 million board feet.

Mine timber production is omitted from this paper because a separate report has been prepared to cover the wood consumption of the mining industry. (Forest Survey Release No. 15, California Forest and Range Experiment Station.)

1/ All revisions are minor, and none of them include production figures.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Information presented here was obtained by mailing a questionnaire to all known veneer, pulp, and shingle mills, and to concentration yards and preservation plants handling poles and piling. An exception was made for equipment-manpower "sample" plants, where the enumerators collected production figures while obtaining data on equipment, supplies, and manpower. After some follow-up of the mail canvass, an 85 to 100 percent response was obtained in the various segments of the industry, thus insuring a sound basis for estimating total production.

The output of miscellaneous timber products in California in 1950, and comparison with 1948 and 1946 are shown in Table 1. Tables 2 to 7 present the data by tree species and region for each product, poles and piling being combined in the last table. The data represent logs and bolts cut in 1950 for conversion into products during that year or for stock-piling until the following year, and are shown by region of origin. For this report, the two major timber regions of California are: the Redwood region, which includes the north coastal portion of the State, and the Pine region, which embraces the rest of the State.

HIGHLIGHTS

Logs for plywood and pulpwood, little of which was produced in 1946, are now an important segment of the timber industry in California. Production of plywood logs has doubled, and pulpwood production has tripled since 1948. Increases in both products are greater in the Redwood than in the Pine region. Both new plants and increased production in existing plants are responsible for the additional log output.

On the other hand, production of container veneer and cooperage logs and bolts has decreased since 1948. The decrease in veneer is primarily due to one large plant ceasing operations in 1949. That in cooperage continues a trend observable between 1946 and 1948, and is primarily due to competition from other types of containers. Shingle and sawed shake bolt production was less in 1950 than in 1946; but most of the decrease has taken place in the Pine region, for production in the Redwood region has dropped only slightly. Pole production was less in 1950 than in 1946, but more piling was produced in 1950.

Douglas-fir was the leading species by volume for all but two of the products listed. Most of the Douglas-fir came from the Redwood region. Of the two exceptions, redwood was the leading species for shingles and sawed shakes, and ponderosa pine for poles. Ponderosa pine was the second species by volume for plywood logs, veneer logs, and piling. Redwood was also used to some extent for plywood, pulp, cooperage, and piling.

Table 1.- Production of logs and bolts by commodity and region, California, 1946, 1948, 1950

Commodity and region	Unit	1946[1/] Quantity	1948[2/] Quantity	1950 Quantity	Percent change 1948 to 1950
PLYWOOD[3/]	M bd.ft.				
Redwood region		0	[4/]36,680	93,445	+155
Pine region		15,462	34,760	49,040	+ 41
Total both regions		15,462	71,440	142,485	+ 99
PULPWOOD	M bd.ft.				
Redwood region		0	9,700	38,685	+299
Pine region		2,241	6,227	10,155	+ 63
Total both regions		2,241	15,927	48,840	+207
CONTAINER VENEER	M bd.ft.				
Redwood region		15,730	[4/]14,140	14,180	+ 0
Pine region		17,075	17,610	3,725	- 79
Total both regions		32,805	31,750	17,905	- 44
SHINGLE & SAWED SHAKE	M bd.ft.				
Redwood region		13,590	no survey	13,550	--
Pine region		3,720	no survey	1,290	--
Total both regions		17,310		14,840	
COOPERAGE	M bd.ft.				
Redwood region (none in Pine region		11,306	7,256	5,275	- 27
POLES	Pieces				
Both regions		21,690	no survey	12,325	--
PILING	Lin. ft.				
Both regions		172,460	no survey	547,950	--

[1/] From Forest Survey Release No. 6, California Forest and Range Experiment Station.

[2/] From Forest Research Note No. 63, California Forest and Range Experiment Station.

[3/] Compiled from consumption and stocks data provided by Bureau of the Census, U. S. Dept. of Commerce, and from Station records.

[4/] Production of one mill peeling green veneer for plywood plants, which was included with veneer data in Forest Research Note No. 63, is here shifted to plywood.

Table 2.- Estimated plywood log production[1] by species and region, California - 1950

Species	Redwood region	Pine region	Both regions: Volume	Both regions: Percent
	M bd.ft.	M bd.ft.	M bd.ft.	
Douglas-fir	88,265	2,750	91,015	64
Ponderosa pine	0	39,545	39,545	28
Others[2]	5,180	6,745	11,925	8
All species	93,445	49,040	142,485	100
Number of plants	9	4	13	-

[1] Computed from log consumption and stocks data, provided by Bureau of the Census, U. S. Dept. of Commerce, with adjustments based on local information.

[2] Primarily redwood and true firs.

Table 3.- Pulp log and bolt production[1] by species and region, California - 1950

Species	Redwood region	Pine region	Both regions: Volume	Both regions: Percent
	M bd.ft.	M bd.ft.	M bd.ft.	
Douglas-fir	26,445	0	26,445	54
Redwood	12,240	0	12,240	25
True firs	0	[2] 7,340	7,340	15
Eucalyptus	0	1,855	1,855	4
Monterey pine	0	960	960	2
All species	38,685	10,155	48,840	100
Number of plants	([3])	([3])	[3] 3	-

[1] Pulpwood measured in cords converted to M bd. ft. on the basis of 1 cord = 500 bd. ft.; e.g. 48,840 M bd. ft. = 97,680 cords.

[2] Includes a very small amount of ponderosa pine.

[3] Plants not allocated to regions because one plant obtained logs from both regions.

Table 4.- Container veneer log production by species and region, California - 1950

Species	Redwood region	Pine region	Both regions Volume	Both regions Percent
	M bd.ft.	M bd.ft.	M bd.ft.	
Douglas-fir	13,560	0	13,560	76
Ponderosa pine	0	3,725	3,725	21
Sitka spruce	620	0	620	3
All species	14,180	3,725	17,905	100
Number of plants	2	6	8	-

Table 5.- Estimated production of bolts for shingles and sawed shakes[1/] by species and region, California - 1950

Species	Redwood region	Pine region	Both regions Volume	Both regions Percent
	M bd.ft.	M bd.ft.	M bd.ft.	
Redwood	[2/]13,550	0	13,550	91
Bigtree	0	860	860	6
Sugar pine	0	430	430	3
All species	13,550	1,290	[3/]14,840	100
Number of plants	42	14	56	-

[1/] Shingle and shake bolts measured in cords were converted to M bd. ft. on the basis of 1 cord = 715 bd. ft.; e.g. 14,840 M bd. ft. = 20,760 cords.

[2/] Del Norte and Humboldt Counties produced 10,300 M bd. ft. and Mendocino and coastal counties to the south produced 3,250 M bd. ft.

[3/] Of this total, 12,890 M bd. ft. were reported by 46 mills, the balance being the estimated production of 10 non-reporting mills known or believed to have been active.

Table 6.- Cooperage log production by species and region, California - 1950

Species	Redwood region Volume	Redwood region Percent
	M bd.ft.	
Douglas-fir	3,755	71
Sitka spruce	1,160	22
Redwood	200	4
Grand fir	160	3
All species	5,275	100
Number of plants	[1]1	

[1] Permission to publish these statistics has been granted by the producer.

Table 7.- Estimated production of poles and piling[1] by region and species, California - 1950

Region	Species	Poles Pieces	Poles Cu.ft.	Piling Lin.ft.	Piling Cu.ft.
Redwood region	Douglas-fir	280	4,355	219,560	148,230
	Redwood	-	-	107,800	84,625
	Subtotal	280	4,355	327,360	232,855
Pine region	Ponderosa pine	7,035	108,740	168,410	91,845
	Douglas-fir	5,010	77,425	-	-
	Subtotal	12,045	186,165	168,410	91,845
Undetermined	Eucalyptus	-	-	52,180	32,675
Both regions	Douglas-fir	5,290	81,780	219,560	148,230
	Ponderosa pine	7,035	108,740	168,410	91,845
	Redwood	-	-	107,800	84,625
	Eucalyptus	-	-	52,180	32,675
	All species	12,325	190,520	547,950	357,375

[1] One of the smaller concentration yards of a total of six obtain ing poles and piling from California failed to report its volume. This ha been estimated for inclusion in this table.

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EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

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FORESTRY DEPARTMENT
UNIVERSITY OF T

INDUCING EARLY PRODUCTION OF PINE POLLEN

By N. T. Mirov

In order to shorten the time required in producing new hybrids of pines it is necessary to have both male and female flowers as early in the life of the tree as possible. This paper describes experiments seeking to induce the formation of male flowers. It was reasoned that if young seedlings were grafted on a mature tree that produces flowers in abundance, the seedlings might produce flowers, too. Early flowering, it was thought, may be caused by the transfer of a flowering hormone across the graft and by the existence of a proper nutritional balance between carbohydrates and nitrogen in the mature tree.

From previous experience[1] it was known that within two large subdivisions of the genus, the hard pines and the white pines, intergrafting can be done without any difficulty. The seedlings to be grafted were transplanted into gallon cans in the fall. The following spring they were grafted by inarching to a mature ponderosa pine, prolific in its production of pollen and conelets. Five transplants of each species were kept in gallon cans in the lathhouse as controls.

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[1] N. T. Mirov. 1940. Tested methods of grafting pines. Journal of Forestry 38(10): 768-777.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

The inarched seedlings were left in the cans for one month. After that period the grafting union was firm enough to permit clipping the seedling roots off. The shock of grafting was considerable. During the first summer the grafted seedlings just held their own, but next summer much growth took place, and the wounds completely healed and calloused. Flowering started at the beginning of the third growing season, i. e., about 2 years after the seedlings were grafted (fig. 1). None of the controls produced flowers in this period.

A few individuals among the trees planted at the Institute of Forest Genetics[2/] have produced pollen at 2 to 4 years of age; but as a general rule for the species used in this test, 7 years or more have been required for pollen production. Besides inducing early flowering, the grafting technique makes collection of experimental material more certain and convenient.

The following pine seedlings grafted on the mature ponderosa pine were caused to flower:

1. P. Torreyana Parry (Torrey pine)
2. P. contorta var. latifolia Engelm. (lodgepole pine)
3. P. sabiniana Dougl. (Digger pine)
4. P. ponderosa Laws. (ponderosa pine)
5. Hybrid between P. jeffreyi Grev. and Balf., and P. coulteri D. Don.

Grafted slash pine (P. caribaea Morelet) seedlings did not produce pollen during the 2 years. No female flowers (conelets) have been produced on the grafted seedlings, probably because the seedlings were grafted to the lower part of the crown, which was producing an abundance of male flowers, while the upper crown, as usual, produced female flowers (conelets). It is possible that the grafted seedlings received only a male flowering hormone. At present, experiments are being conducted at the Institute of Forest Genetics on inducement of female flowers.

[2/] A field branch of the California Forest and Range Experiment Station located near Placerville, California.

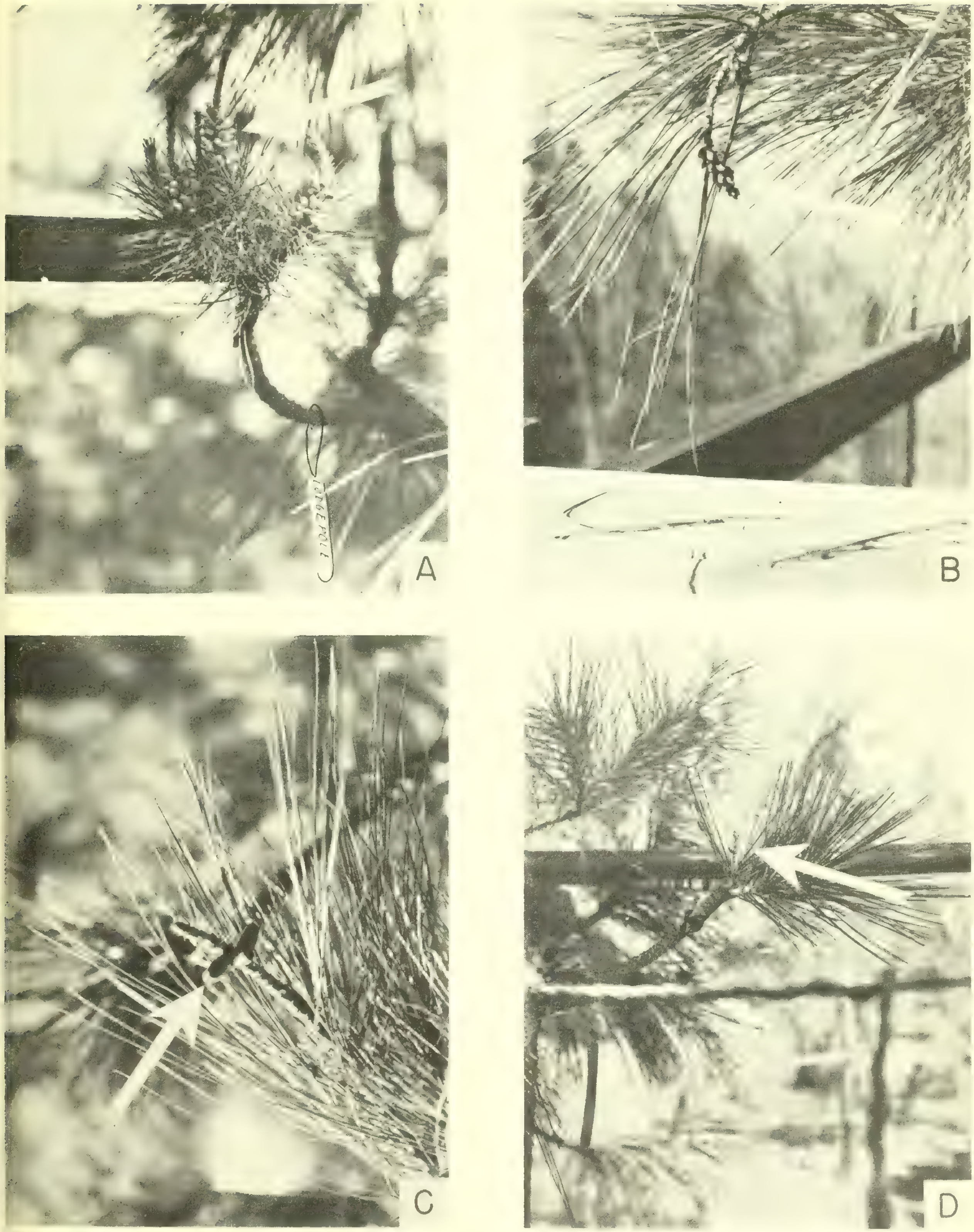

Figure 1.-Grafting pine seedlings on a mature tree induces production of pollen and thus speeds tree-breeding work. Catkins are shown above on seedlings of: A, *Pinus contorta* var.*latifolia*; B, *P. sabiniana*; C, *P. torreyana*; D, *P. Jeffreyi* x *P. Coulteri* hybrid; all grafted on mature ponderosa pine.

Study Area and Objectives

The timber stands of the study area, situated about 30 miles east of Sonora, are typical of the high site-quality sugar pine-fir type of the western slopes of the Sierra Nevada. Elevation of the study area is from 6,000 to 6,500 feet, near the upper elevational limit of sugar pine in central California. The terrain is characterized by gentle to steep slopes, scattered benches, small feeder streams, and rocky ridges. Except for the tops and upper slopes of rocky ridges, all the land is Site A-200 or Site I-175 (Region 5, Forest Service, site classes based on the height-age relation of dominant trees).

The merchantable volume (stand over 11.6 inches d.b.h.) was approximately 44 percent sugar pine, 39 percent white and red fir, 13 percent California incense-cedar (*Libocedrus decurrens* Endl.), and 4 percent Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.). The main brush species present were manzanita (*Arctostaphylos patula* Greene), whitethorn or snowbrush (*Ceanothus cordulatus* Kell.), deerbrush (*Ceanothus integerrimus* Hack and Arn.), and chinquapin (*Castanopsis sempervirens* Dudley).

Of the 200 acres logged, 58 acres or approximately 30 percent, were treated as regeneration areas. These unit areas, where silvicultural treatments were aimed at securing sugar pine reproduction, varied in size from one-fifth to 3 acres. Some were clear-cut with seed trees left around the border for natural reproduction. The others were clear-cut for seeding and planting. The cut on these unit areas was 88,000 board feet[5/] per acre, resulting in large accumulations of slash. Slash disposal and site preparation were done on the regeneration areas.

On the unit areas cut by other methods (group release and improvement) the original stand was 75,000 board feet per acre, of which 29,000 feet were cut. The resultant slash was not too great a fire hazard because the bare regeneration areas and skid trails served as effective firebreaks. Consequently the slash was not piled.

The objectives of slash disposal and site preparation were threefold:

1. To clear logging debris, brush, and unwanted trees from regeneration areas to facilitate seeding and planting.

2. To disturb the ground and expose mineral soil, thus providing a seedbed for sugar pine.

3. To reduce the fire hazard due to large accumulations of slash.

[5/] Stand above 11.6 inches d.b.h. gross volume Scribner Decimal C Log Rule.

After the logs were yarded from a regeneration area, the slash was piled and the mineral soil exposed in one operation. Plot data[6] indicate that given an even start sugar pine can compete successfully with both fir and brush. But if establishment of the pine is delayed, brush will invade the ground cleared by cutting and will prevent subsequent establishment of pine unless costly eradication of brush is carried out. Eradicating well-established, vigorously growing brush is much more difficult than eradicating the less-vigorous brush occupying only part of the area immediately after logging. Thus the timing of this operation was important. The site had to be prepared by September on areas that were to be regenerated naturally after seedfall. On artificial-regeneration areas the site had to be readied and planted as soon after logging as possible so that brush or inferior tree species would not take control of the area. Also, to reduce the fire hazard and to put all the land back into a productive state, the slash piles had to be burned as soon as possible.

Equipment and Technique

In 1948, two tractors, one of 80 hp. and one of 130 hp., with cable-controlled angledozer blades were used at different times to pile slash. In 1949 only the 80 hp. tractor was used. A 43 hp. tractor was tried, using a cable-controlled angledozer equipped with brush-piling teeth designed by Region 6, U. S. Forest Service. These teeth were constructed so the dozer blade could be floated, that is, freed from cable support, part of the time a load was being pushed. Thus most of the disturbed soil could pass between the teeth and not be picked up in the load of slash. In practice, however, many root crowns of brush and saplings also passed between the teeth, so the brush eradication was not as effective as desired. Also, the 43 hp. tractor proved too small and unstable for the task, and it was soon abandoned in favor of the 80 hp. tractor.

The most satisfactory working team consisted of a job supervisor, a cat skinner, and swamper. The supervisor examined regeneration areas before work began on them and organized the work plan by:

1. Establishing the best boundaries of the area to be cleared for regeneration;

2. Establishing locations for piles or windrows of slash; and

3. Marking good patches of sugar pine seedlings or saplings that were to be saved. Instructions were given to the cat skinner and swamper in considerable detail. After the crew was trained the supervisor spent only an average of 2 hours a day laying out the areas and inspecting them as clearing was completed.

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[6] Fowells, H. A. 1944. Site preparation as an aid to sugar pine regeneration. California Forest and Range Experiment Station. Forest Research Note No. 41. 5 p. Berkeley, Calif.

The cat skinner and swamper were normally part of the yarding crew in 1949. Their yarding assignment was to ground-skid logs from patches of reproduction and bunch the logs in openings so that a tractor and arch unit would not have to be operated in the reproduction.[7] The clearing operation was balanced with the yarding work so one crew could do both jobs satisfactorily. Using a two-man crew for the clearing operation alone, as was done in 1948, proved inefficient for this 55,000- to 60,000-board feet per day logging operation.

Clearing was begun as soon as a few adjoining regeneration areas were logged, and was completed before the time of seedfall in 1948. In 1949 the sugar pine seed crop failed, so clearing was completed by the end of the logging season to make the area ready for seeding and planting.

Besides the slash created by an average cut of 88,000 board feet per acre, the cull logs, windfalls, high brush, litter, and scattered reproduction were moved into the piles in 1948. Chokers were set on some cull logs and other material to help move them to the piles. The dozer blade was run over the regeneration area so that the mineral soil was everywhere exposed as a seedbed.

Since the sugar pine seed crop failed in 1949, the clearing that year was designed merely to facilitate planting and to reduce the fire hazard. Some large windfalls and cull logs were left unpiled. Moving them required much time and power, and it was obvious that most sizes encountered would not interfere with the 6- by 6-foot spacing of seedlings. No special attempt was made to expose the mineral soil; yet in the process of rooting out brush and piling slash, the bulldozer exposed the soil on nearly all of the area. As a result the site was considered sufficiently prepared to act as a seedbed for natural regeneration the second year, too.

Slash piles were located on stump concentrations whenever possible. On some of the larger regeneration areas having steep slopes, slash was piled in windrows along contours. Some unburned slash and a terrace of soil remained in the windrows after the burn and served to check erosion. All slash piles and windrows were located so as to eliminate the possibility of scorching reserve timber when the slash was burned. All piles in the cleared area were kept as compact as possible so that they would burn clean and occupy a minimum of ground space. Experience with piling and burning in 1948 indicated that the tractor operator should make an effort to keep as much dirt as possible out of the piles. Soil mixed with organic material creates poor burning conditions and may cause some piles to smoulder longer than is desirable. Pushing slash uphill should be avoided as much as possible.

7/ Cosens, Richard D. 1952. Reducing logging damage. California Forest and Range Experiment Station. Forest Research Note No. 82. Berkeley, Calif.

Small groups of sugar pine seedlings and saplings were occasionally found in regeneration areas before clearing. When the trees had a spacing of approximately 6 by 6 feet or closer (roughly 1000 per acre), they were saved. Other species were cut if present, the trash was thrown out of the sugar pine group, and the tractor was kept out. On the other hand, no special attempt was made to save scattered young trees not meeting the spacing requirement.

As the object of clearing was to get sugar pine established, seedlings, saplings, and scattered poles of other species, and high brush were eliminated from the regeneration areas. For various reasons it was sometimes difficult for the dozer blade to push these plants out without also scooping up a large quantity of soil. The plants were left, and the swamper cut them with an axe. (A $2\frac{1}{2}$-pound single-bitted axe was best for this job.) He also cut off some saplings knocked flat by the logging operations and other small trees and brush that resisted the dozer blade. Cleaning up the small trash on edges of piles and windrows was best done by hand and with the aid of a pitchfork.

To reduce fire hazards, all men engaged in the clearing operation coordinated their work so that no stringers of trash were left lying between slash piles and the reserve timber. This eliminated the danger of fire creeping to the live stands during the burning. Snag falling was done after clearing was completed. The fallers cut a firebreak section out of any snag that extended from a slash pile into the reserve timber. On his last inspection before the burning, the job supervisor carried a shovel to clear up any shattered wood from snags or other trashy fuel near slash piles.

Burning had to wait until the woods were wet because many large piles of slash had been accumulated. Most piles burned very hot for a few hours, and some carried a moderate amount of heat for several days; some piles smouldered over winter. An occasional inspection of the burning area was made during May, June, and July of the following season.

Costs

Records of time and costs were kept for the slash disposal and site preparation phases of the job for both 1948 and 1949 (table 1). The lower cost in 1949, \$37.38 per acre cleared, contrasted with \$58.55 per acre cleared in 1948, is largely the result of increased experience. A better clearing blade for the tractor and more experience in this type of work should reduce the cost even more. The cost of slash disposal and site preparation is presented in table 1 in three ways; (1) Per acre of regeneration area, (2) per acre of gross area logged during season, and (3) per thousand board feet, net landing scale, all timber cut. An operator's costs may be calculated from the man-day and hour-meter data given.

Table 1.- Time-cost table for slash disposal and site preparation

Item	Labor				Equipment				Total labor and equipment cost	
	1948	1949	1948	1949	1948	1949	1948	1949	1948	1949
	Man days		Dollars		Hours		Dollars		Dollars	
Total	60	43.5	$824.15	$622.68	155	62	$1049.45	$349.10	$1873.60	$971.78
Per acre of regeneration area	1.88	1.67	25.75	23.45	4.84	2.38	32.80	13.43	58.55	37.38
Per acre, gross area logged	.67	.40	9.16	5.66	1.72	.56	11.66	3.17	20.82	8.83
Per M b.f. all timber cut	.017	.010	.232	.141	.044	.014	.295	.079	.526	.220

Notes: 1. Equipment use rates based on hour-meter readings: 43 hp. tractor - $2.75; 80 hp. tractor - $6.55; 130 hp. tractor - $7.45. Rates include charges for operation (fuel, grease, etc.), repairs, and depreciation. Hours of use: 1948--80 hp. tractor, 117; 130 hp. tractor, 38. 1949--43 hp. tractor, 15; 80 hp. tractor, 47.

2. Acres cut: regeneration--32 acres in 1948, 26 acres in 1949; gross--90 acres in 1948, 110 acres in 1949.

3. Net volume cut, Scribner: 1948, 3,559,140 board feet; 1949, 4,413,460 board feet.

4. Labor costs consist of straight wages for an 8-hour day; no allowances for leave and holiday pay. Labor of supervisory personnel included. Average wage for an 8-hour day: 1948, $13.74; 1949, $14.31.

Discussion

It is obvious that possibilities for clearing slash from regeneration areas have been only briefly investigated. New machines, tools, and methods should be tried. There are now on the market various types of land-clearing blades for attachment to tractors, most of them being arrangements of different kinds of teeth. Tests may show some of these blades to be satisfactory. If they all prove inadequate for the job, good ones should be designed. The ideal clearing blade should cut off live brush and small trees below ground level and move the slash to piles without picking up soil.

Whether or not the methods tried in slash disposal will result in site deterioration is a question which should be investigated. It must be remembered that a bare mineral soil is considered to be essential for establishing sugar pine reproduction by means of natural seedfall.

To date the effect of burned slash piles on restocking has not been thoroughly investigated. The information available[8] shows no significant difference in survival of seedlings between areas where slash piles were burned and adjacent areas of bare soil.

In some localities it might be possible to sell limbs and chunks for firewood or other uses, either before or after slash is piled. Large accumulations of such material in regeneration areas, which are fairly accessible over skid trails, might make the recovery of firewood, shake, or post material an attractive enterprise for local residents.

Complete elimination of sprouting brush species does not result from the slash disposal methods described here. Some species, like whitethorn and chinquapin, sprout quickly. In an effort to control the sprouts as they appear, techniques of chemical spraying are being tested. But complete elimination of brush may not be necessary since slash disposal and site preparation are done only to give pine reproduction the initial competitive advantage it needs to keep ahead of brush growth.

Present experience indicates that the preparation of regeneration areas to receive seed or planting stock can be done at a reasonable cost, and at the same time provide fireproofing measures for the logging area.

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[8] Fowells, H. A., and G. H. Schubert. 1951. Recent direct seeding trials in the pine region of California. California Forest and Range Experiment Station. Forest Research Note No. 78. 9 p. Berkeley, Calif.

FOREST RESEARCH NOTES

U.S.DEPARTMENT OF AGRICULTURE
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REDUCING LOGGING DAMAGE[1]

By Richard D. Cosens, Forester,
Division of Forest Management Research

Reducing logging damage to reproduction and residual stands is an important part of harvesting the old-growth forests of California. Much of the overmature timber is on areas with an acceptable stocking of advance growth. When the old trees are harvested, the advance growth is scarred, deformed, broken, or killed outright. Insects and disease attack the broken and scarred trees, and the quantity and quality of wood grown for the next harvest is reduced. Sometimes the advance growth is so severely damaged that the stand must be regenerated. This is costly and of course extends the time that land owners must wait until the next harvest.

The extent of damage varies with stand conditions, forest types, topography, type of equipment, and attitude of the loggers. The more frequent sources of damage are:

1. Unnecessary and improperly located roads, landings, and yarding trails.
2. Improper falling.
3. The use of tractor-arch units in young stands.
4. Loose supervision of logging crews in their efforts to reduce damage.

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[1] The plan for reduction of logging damage was made and carried out under the direction of W. E. Hallin, in charge of silvicultural investigations, Division of Forest Management Research. Acknowledgment is made to David C. Maul, formerly of the Division, for the use of material from progress reports made while he was carrying out the plan in the field.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Agriculture--Berkeley

A general policy of careful logging is not enough to reduce damage; besides the policy, specific measures must be designed to do the job. This article describes the measures taken to reduce logging damage on an experimental logging project conducted by the Experiment Station in 1948 and 1949. The logging project was part of a trial application of Dunning's Unit Area Control[2] to the sugar pine-fir type, common on the west slopes of the Sierras in central California. Logging was done by Experiment Station crews.

The Logging Project

The trial was carried out on 200 acres of the Stanislaus Experimental Forest, about 30 miles east of Sonora, California. The topography ranged from relatively level areas to steep slopes. The forest was composed of many small unit areas, or natural groupings of trees. Each unit was uniform in age, species, and stocking; and enough different units were present to classify the forest as a whole as an all-aged, mixed-conifer stand. Unit areas containing advance growth occupied 70 percent of the logging area and were of three general types, each requiring a different silvicultural treatment in the first cutting cycle. Groups of young trees with no overstory received no cutting. Groups of reproduction with an overmature overstory received a group release cut. And groups of mature and immature trees with a few scattered overmature trees received an improvement cut. For these three types of areas the cut overaged 6.6 trees, or 29,000 board feet per acre, and the reserve averaged 60 trees, or 46,000 board feet per acre. The reserve also included numerous poles under 11.6 inches d.b.h. The other 30 percent of the area consisted of groups of overmature trees, in units of one-fifth to 3 acres in size, with inadequate stocking of advance growth. These areas were clear cut and the ground was prepared for regeneration by bunching the brush and slash and exposing the mineral soil with a bulldozer.[3]

The measures used to reduce the logging damage on this project are discussed under three headings:

1. Advance planning,

2. Carrying out the plan, and

3. Training and supervision.

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[2] Hallin, William E. 1951. Unit area control in California forests. California Forest and Range Experiment Station. Forest Research Note No. 77. 8 p. Berkeley, Calif.

[3] Gordon, Donald T., and Richard D. Cosens. 1952. Slash disposal and site preparation in converting old-growth sugar pine-fir forests to regulated stands. California Forest and Range Experiment Station. Forest Research Note No. 81. 7 p. Berkeley, Calif.

Advance Planning

A logging plan was made before actual logging started. Much of the planning was done as the timber was marked for appropriate silvicultural treatments. This made it possible to coordinate forestry and logging phases of the operation, eliminating the need to adjust road or landing locations after logging began. Thus, the plan resulted not only in less damage to the young trees but also in a more efficient operation. Preparation of the plan was done in four steps: (1) Locating secondary roads and landings, (2) marking timber and selecting yarding methods, (3) preparing logging maps, and (4) outlining cutting patterns.

Roads and Landings

Tentative locations for secondary roads, landings, turn-arounds, and the area to be served by each landing, were first determined from aerial photographs and a topographic map. Then when the logging area was checked on the ground, the final locations were marked on a map and on the ground. The logging superintendent and a forester worked together in selecting these locations.

Coordination of the road system with the rest of the logging plan was the most important feature of road location as far as reducing logging damage was concerned. Secondary or spur roads were located so that disturbances to the reserve stand and to the ground were minimized. Roads were routed through natural openings, and cuts and fills which might erode were avoided when practicable.

Each landing was located so that the main yarding trails entering it would do a minimum of damage to reproduction and to stream channels. Natural openings in the timber were utilized. Locations were made to tie in with the existing road system, so the landing was on the edge of a secondary road if possible. For safety reasons, landings were not placed on roads having through-traffic from other areas. Some of the landings used in the first cut were located for permanent use in order to minimize both the area made unproductive by landings and spur roads and the cost of future construction.

The area to be yarded to each landing was determined by the topography, yarding distance, location of the landing itself, and the location of adjacent landings. The desired maximum yarding distance was 1,200 feet, but in some cases distances up to 2,000 feet were necessary because of the topography. To avoid erosion hazards, boundaries of each setting were laid out so that yarding trails would not cross small streams. Thus streams as well as ridges affected the location of setting boundaries. For example, in 1948 two landings were located relatively close together, one on the north side of a stream and the other on the south side.

Marking and Yarding Methods

Marking was done by a two-man crew. One man selected the unit areas that were to be cut for regeneration, group release, or stand improvement. He marked and numbered the trees, located and flagged the arch trails, and made the necessary tree measurements. On unit areas marked for group release or improvement, he also designated the places where ground skidding should be used instead of arch yarding. The other man recorded tree data and made a rough map of the landing area. They began work at the landing, thus making it easier to select arch trails as marking proceeded away from the landing. The logging superintendent and the forester checked the arch trails and ground skidding area before logging started at each setting.

Arch-trail locations were determined by five main objectives. First, the trails serviced the entire landing area so there would be no reason to make additional trails at the time of logging. Second, the number of trails was kept to a minimum, with branch trails joining the main ones as soon as feasible. Third, stream crossings were kept to a minimum by locating arch trails on both sides of the stream where it was impracticable to locate separate landings. These trails were located as far away from the stream edge as practicable in order to minimize disturbances on or near stream banks. Fourth, patches of reproduction were avoided by running the arch trails through natural openings, or openings resulting from cutting. Trails were routed around young stands where there was to be no cutting, and occasionally short adverse grades were accepted to avoid patches of reproduction. Fifth, the trails were located to avoid long or steep adverse grades, unnecessary distances, and sharp turns. The trails were marked on the ground by flagging trees and bushes with strips of paper or cloth. Occasional trees that could not be avoided when locating trails were marked for cutting. The trails were rechecked when the marking was completed to make sure they were located properly in respect to the objectives and in relation to other trails. Tractor-arch units were confined to these trails except for the actual pick-up of logs. Use of these designated trails contributed much to the reduction of logging damage.

Ground skidding was designated for areas containing reproduction or advance growth that would be severely damaged by the maneuvering of a tractor and arch. This included most of the unit areas marked for a group-release cut and several of the unit areas marked for an improvement cut. Since many loggers are prone to consider dense, small reproduction as brush, special care was taken to designate these spots for ground skidding. Slopes too steep for the tractor and arch were also marked for ground skidding. Within all ground-skid areas logging was done with a skid cat.

Regeneration cuts, as mentioned previously, were made on unit areas having overmature trees with little or no advance growth. All trees on these unit areas were marked, and the boundaries of the areas were plotted by the mapper.

In 1948 the direction of fall was marked by a painted line on trees to be cut, so advance growth would not be damaged. This practice was later discontinued because the same objective was adequately achieved by crew training and supervision, with a considerable saving of time.

Logging Maps

Logging maps similar to the one in figure 1 (at end of paper) were prepared for all landings. As marking progressed, the mapper sketched in the details. Relative, rather than exact locations were plotted. Details mapped were roads, streams, rock outcrops, landings, arch trails, regeneration units, places where ground skidding was necessary and the trees marked for cutting. For the regeneration unit areas, only the numbers of the first and last tree were plotted. Where the marked trees were not grouped, the position of each tree was plotted. The maps were duplicated by the ozalid process for distribution to loggers.

Cutting Pattern

A cutting pattern for each landing was also prepared in advance of logging. This was done to prevent any conflict between yarding and cutting that would necessitate new arch trails and landings or that would lower safety standards by having the two crews too close to each other. Using volume data from marking sheets and tree locations from logging maps, cutting strips were drawn on the map and numbered for cutting priority. The first strip to be cut included the trees near a main arch trail. The objective was to finish the cutting on an area adjacent to an arch trail before yarding began. Basing the cutting strips on arch trails in this way permitted a more even daily production by balancing long skids with short skids. The first cut on areas to be cut in two stages was designated for cutting as soon as possible. Then this cut could be yarded, and the second cut and yarding completed before the landing was moved.

On logging operations where falling is completed on an entire setting before yarding begins, a planned cutting pattern is necessary only for areas that are cut in two stages.

Carrying Out the Plan

Copies of the landing-area maps were distributed to each set of fallers, the head rigger (called head choker setter on some operations), the skid-cat choker setter, the logging superintendent, and the forester. Besides marking the trees for cutting, the forester trained and supervised the logging crew on the planned methods of reducing logging damage. Each man receiving a map was shown by the forester how he could use it most advantageously.

Use of Maps

The fallers made use of the maps in two ways. When falling a tree they knew the location of the arch trail and were able to place the tree so that yarding could be done with the least amount of damage. Many times the location of the arch trail was the controlling factor in determining the direction of fall. Of course other factors--such as the lean of a tree, the risk of breakage in falling a tree over windfalls or rough ground, and the risk of damaging advance growth--also influenced the direction of fall. Regardless of the other factors, on steep slopes the trees were dropped up or down the hill, rather than across the slope, in order to prevent damage to advance growth from rolling logs and to reduce the accident hazard for the yarding crew. The maps also aided the fallers in locating marked trees and made it unnecessary to check whether isolated trees were marked. Only one tree out of approximately 2500 marked was missed by the fallers. It was felt that the map and the practice of numbering the trees were responsible for this excellent showing.

The yarding crew found that the maps made it easier to follow the arch trails and to determine which trail the logs should be yarded to. This can best be illustrated by referring to the map in figure 1. Assume that the yarding is proceeding in a clockwise manner and that the trees numbered 53 to 56 are being yarded. The map shows clearly that the next group, trees numbered 47 to 52 should be skidded to another trail rather than the one now being used. The reason for using another trail is that a patch of reproduction grows between trees 49 to 53. Had the map not been used, this patch could have been partially destroyed by running an arch trail through it. The crew could also see where ground skidding was necessary, so the forester did not have to be constantly with them.

The logging superintendent found the maps valuable in directing the yarding crews. Instructions were clearer when referenced to the map, and yarding distances were more easily balanced. He was also able to determine when and for how long it would be necessary to use the skid cat at each setting. And the forester found the maps useful in checking the crews to see that they were following the logging plan.

Two-stage Cutting

Logging was done in two stages to reduce breakage and damage to the residual stand where a large volume of timber was removed. This was necessary on about 30 percent of the area, primarily the regeneration units. The fallers first cut from 50 to 60 percent of the marked trees on these units and all the marked trees on the rest of the area. After these logs were yarded the remaining trees were cut. This practice also lowered the time needed for limbing and bucking. The volume removed on each cut was always more than 20,000 board feet per acre, and logging costs per thousand were not increased by two-stage cutting. The cutting pattern was arranged so that both stages of logging could be done without moving landings. To do this, the fallers were assigned to cutting strips in the two-stage areas as soon as the trees around the landing and main arch trails had been felled.

Use of Skid Cat

Ground-skidding areas were logged with a skid cat rather than the tractor-arch unit. The skid cat had a smaller turning radius and greater maneuverability and consequently did far less damage to the advance growth than the tractor-arch unit. With the skid cat it was possible to yard individual logs down the line of the tree. This was done by pulling out the first log to an opening, then backing down the line of the tree to the next log, and so forth, until the entire tree was yarded out. For some trees the winch line was pulled out to the log by the choker setter in order to save trees that would be damaged by backing the cat all the way. As can be seen from the map (fig. 1), regeneration units are scattered throughout the stand. Because these unit areas were clear-cut for regeneration, they made ideal transfer points. That is, logs removed by the skid cat were bunched in the regeneration units, and the tractor-arch unit took them on to the landing. With this setup little time was wasted by having the skid cat yard only one or two logs at a time.

The crew consisted of a cat skinner and one choker setter. This crew worked approximately one-third of the time on ground skidding. When ground skidding was not in progress, an angledozer was attached to the skid cat and it was used to pile slash, to build spur roads, to build arch trails, and to prepare and clean landings. The division of time for the skid cat varied for each landing.

Daily production was increased by using the skid cat. However, costs of yarding were somewhat higher in areas where it was used. In 1949 yarding was done by one tractor-arch unit with a cat skinner and two choker setters working all the time, and the skid cat with a cat skinner and one choker setter working only one-third of the time. The average net scale at the landing was 66,000 board feet per 8-hour day. This is a higher daily production than one tractor-arch unit can ordinarily sustain on similar topography in this forest type.

Training and Supervision

Training the logging crew was one of the most important measures in reducing logging damage. Without proper training the other measures outlined in this paper would lose their effectiveness. For example, selecting and marking a route for an arch trail is of little value unless the yarding crew is trained to use the trail. Having a skid cat on the job does not necessarily mean logging damage will be reduced. The crew has to be trained to use it properly.

Both the logging superintendent and the forester made a special effort to acquaint all the workers with the objectives of the project. The loggers were made to understand that their job was reducing damage to advance growth as well as getting out logs. Such specific measures as the use of the skid cat and the logging maps were explained to them. The practices peculiar to each job were discussed with each man, and he was shown how he could contribute most effectively to reducing damage. Other points basic in growing a new crop were explained to show why damage should be reduced: How a tree grows, where the clear boards are obtained, how disease and insects attack scarred trees.

Because their past experience had been in extensive stands of overmature virgin timber, many members of the logging crew were aware only of the need to harvest the existing trees. It was important, therefore, to emphasize the loggers' role in growing a new crop of timber. All these points were discussed with the men at the beginning of the season and whenever new men were hired.

The forester worked with each falling and yarding crew for two or three days at the beginning of the season. This time was used to show the crew how they could save reproduction and do less damage to the larger advance growth. After these first few days he spent about half of his time with the crews or checking on their work. When crews moved to a new landing he distributed the maps and familiarized the cat skinners and choker setters with the arch trails and the ground skidding areas. Frequent checks were made to see that the falling and yarding crews were doing their jobs correctly. At these times advice was given to men needing it and encouragement to those doing a good job.

Discussion

On this experimental logging project reduction of logging damage was accomplished with present types of equipment by preparing and carrying out a detailed logging plan, and by carefully training and supervising the logging crew.

The ultimate in reducing logging damage, however, will require the development of new equipment, or at least the modification of present equipment. The tractor-arch unit causes an unduly large amount of damage to reproduction because of its size and large turning radius. Smaller, more maneuverable yarding equipment is needed.

There is also a need for more extensive use of lines for yarding logs out of thickets of reproduction without sending tractors into the trees. However, the large line necessary for ground skidding the larger logs greatly restricts the use of lines pulled out by hand for this type of work. A skid cat with an auxiliary drum and fairlead similar to the one developed by I. L. Morgan of New Meadows, Idaho[4] could be used for this purpose. The auxiliary drum allows for the use of a lighter line for winching small logs to the tractor, where they can be transferred to a heavier main line for yarding to the landing. Or possibly the lighter line might be used as a haul-back to pull out a heavier line for winching large logs to the tractor.

To conclude, preventing logging damage will be made easier by:

1. Preparing and carrying out a detailed logging plan aimed at reduction of damage;

2. Properly training and supervising logging crews; and

3. Focusing engineering and logging ingenuity on designing equipment that will lessen damage to the advance growth as well as increase efficiency of yarding logs.

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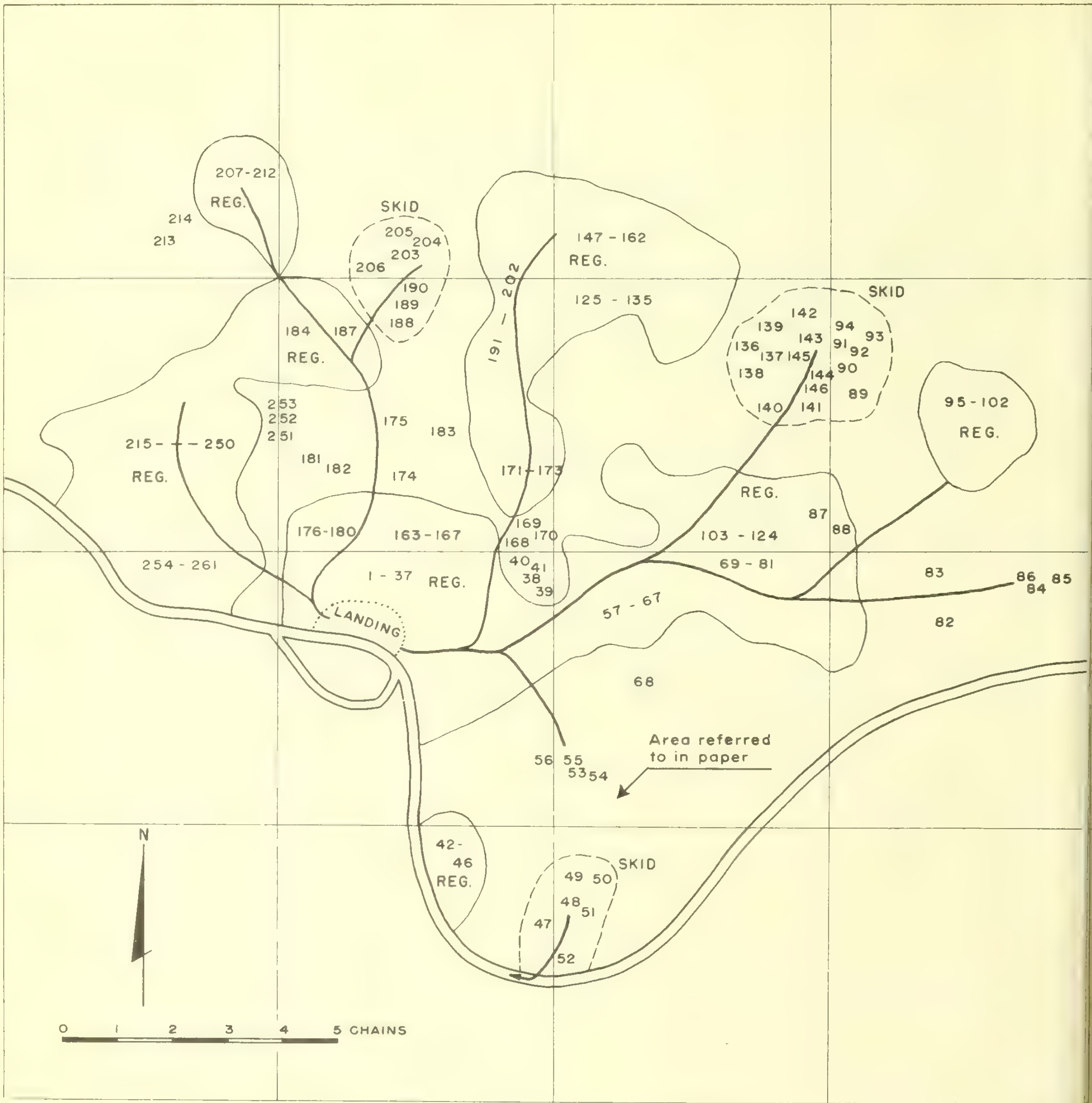
[4] New device increased production of log skidding tractors. Article in the Lumberman 76(9): 74. September 1949.



LANDING 4

LEGEND	
Ground skidding	SKID
Regeneration units	REG
Yarding trails	～
Tree location	1, 68, etc.

VOLUMES	
Total cut	734 M
To be yarded by arch	630 M
To be yarded by skidcat	104 M
Reserve	566 M

Fig. 1 - Logging map of a typical landing.

Seeding & Planting

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 83 July 16, 1952

GERMINATION OF VARIOUS CONIFEROUS SEEDS AFTER COLD STORAGE

G. H. Schubert, Forester,
Division of Forest Management Research

Most conifers do not bear seed each year, but rather at intervals, with good crops occurring two to ten years or more apart. It is necessary, then, to collect seed during good seed years to tide over the poor years. How long seed may be stored safely is thus of great practical importance. This article reports results of germination tests on seed of various conifers stored by this Station from 2 to 24 years. The seed includes some lots previously tested (table 1), and some tested for the first time in 1951 (table 2).

Storage Conditions

Seeds were air-dried immediately after being collected and extracted, and then stored in airtight containers at 41° F. The containers were 5-gallon cans with tight lids. Generally seed of more than one species and a number of different seed lots were stored in a single can. This may not be the best procedure to follow because the can may be opened several times to get seed of different species or lots. Exposing the seed in this way may not be harmful if the relative humidity of the storage room is low and the cans are closed as quickly as possible. Still, it is believed that properly stored seed might give somewhat higher germination than is reported here. By properly stored seed is meant that the following conditions have been fulfilled:

1. Seed is not collected until ripe.

2. Seed is dried to 6 to 10 percent moisture content, depending on the species.

3. Cold storage starts as soon after drying as possible.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

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4. Containers are airtight and of a size which will hold the average amount of seed used at any one time.

5. Storage temperature is in the range of 5° to 32° F. and not higher than 41° F.[1]

6. Seed is used as soon as possible after removal from cold storage.[1]

The above conditions have generally been complied with at this station, except items 4 and 5 and in a few instances, item 1. These exceptions have been noted above and in "Results" where several cases are mentioned in which the seed was believed to be immature at time of collecting.

Wakeley[1] suggests that properly dried conifer seed, such as longleaf, slash, loblolly, and shortleaf pines, can be stored in bags instead of airtight containers if humidity in the cold storage space is low and constant.

Stratification and Germination Tests

Representative samples of 100 to 400 seeds of each species and seed lot tested were stratified in moist sand and peat moss for 60 days at 36° F. This period of 60 days might have been too short for some species, such as sugar pine and possibly the other white pines, which were in cold storage for an extended time. It is generally recommended that sugar pine should be stratified for 90 days or more to obtain maximum germination. Some of the species, such as ponderosa and Jeffrey pine, may not require stratification. However, it was believed that stratification would do no harm and might possibly be beneficial.

Germination tests were conducted in the greenhouse in the same containers (4-inch waxed paper pots) used for stratification. The greenhouse temperature varied from about 55° F. at night to 75° F. at day. The germination tests were closed at the end of 12 weeks. Almost all seed samples had stopped germinating by the end of the ninth week. No germination occurred during the last two weeks. No cutting test was made on the ungerminated seed; therefore, the germinative capacities listed in Tables 1 and 2 are based only on seed which actually germinated.

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[1] Wakeley, Philip C. 1951. Storing southern pine seed. U. S. Dept. Agr. Forest Service, Southern Forest Experiment Station Occasional Paper 123. 13 p. New Orleans, Louisiana.

Table 1.- Germination of various coniferous seeds after prolonged cold storage

Species	Year collected	Years in cold storage [1]	Original germination capacity	Other record of germination: Percent	Other record of germination: Date	Germination capacity 1951
Abies concolor	1937	14	[2] 4	--	--	0
A. concolor	1938	13	[2] 21	--	--	0
A. grandis	1935	16	[2] 8	--	--	0
A. lasiocarpa	1937	14	[2] 9	--	--	0
A. magnifica	1935	16	--	[2] 8	1938	8
A. nobilis	1938	13	[2] 25	--	--	1
Cupressus forbesii	1939	12	[2] 17	--	--	12
Picea englemannii	1937	14	[2] 24	--	--	0
P. pungens	1933	18	--	[2] 56	1937	0
Pinus albicaulis	1936	15	[2] 75	[2] 28	1937	3
P. attenuata	1935	16	--	[3] 69	1945	87
P. balfouriana	1935	16	[3] 86	[3] 72	1945	95
P. canariensis	1933	18	[3] 20	[3] 13	1945	12
P. contorta	1934	17	[3] 91	[3] 77	1945	47
P. contorta	1935	16	[3] 55	[3] 48	1945	40
P. contorta var. latifolia	1934	17	--	[2] 54	1938	47
P. contorta var. latifolia	1935	16	--	[3] 58	1945	28
P. jeffreyi	1933	18	[3] 61	[3] 24	1945	62
P. jeffreyi	1936	15	[3] 65	[3] 67	1945	64
P. lambertiana	1930	21	[3] 26	[3] 8	1945	10
P. lambertiana	1936	15	[2] 31			50
P. lambertiana	1933	18	[3] 93	[3] 32	1945	30
P. lambertiana	1935	16	[3] 77	[3] 13	1945	20
P. lambertiana	1948	3	[4] 90	[5] 65	1950	10
P. monticola	1935	16	--	[3] 44	1945	35
P. monticola	1936	15	[3] 62	[3] 66	1945	40
P. patula	1930	21	[3] 60	[3] 39	1945	61
P. pinea	1933	18	--	[3] 58	1945	32
P. ponderosa	1933	18	--	[3] 90	1945	94
P. ponderosa	1934	17	[3] 72	[3] 76	1945	75
P. ponderosa	1936	15	[2] 59	--	--	46
P. ponderosa	1936	15	[3] 63	[3] 49	1945	32
P. ponderosa	1935	16	--	[2] 84	1937	28
P. ponderosa	1937	14	[2] 56	--	--	50
P. radiata	1930	21	[3] 94	[3] 81	1945	86
P. radiata	1934	17	[3] 78	[3] 36	1945	27
P. radiata	1935	16	--	[3] 71	1945	66

Footnotes at end of table, next page.

Continued next page

Table 1.- Continued

Species	Year collected	Years in cold storage [1]	Original germination capacity	Other record of germination		Germination capacity 1951
				Percent	Date	
Pseudotsuga macrocarpa	1932	19	[3]34	--	--	2
P. macrocarpa	1934	17	--	[2]38	1938	0
P. macrocarpa	1934	17	--	[2]57	1938	1
P. taxifolia	1935	16	--	[2]27	1938	31
Sequoia gigantea	1937	14	[2]18	--	--	8
S. gigantea	1938	13	[2]21	--	--	46
S. sempervirens	1934	17	--	[2] 0	1939	1
S. sempervirens	1935	16	--	[2]14	1938	0

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[1] Stored in airtight 5-gallon cans at 41° F.

[2] From unpublished germination records of James Roof, nursery technician, California Forest and Range Experiment Station 1937-39.

[3] Source: Mirov, N. T. 1946. Viability of pine seed after prolonged cold storage. Jour. Forestry 44(3): 193-195.

[4] From unpublished germination results by the author in the winter of 1948-49.

[5] Source: Fowells, H. A., and G. H. Schubert. 1951. Recent direct seeding trials in the pine region of California. U. S. Dept. Agr. Forest Service, California Forest and Range Experiment Station Research Note No. 78. 9 p. Berkeley, California.

Table 2.- Germination capacity of stored coniferous seeds for which no previous germination records are available

Species	Germination capacity when length of storage was--			
	0-5 years	6-10 years	11-20 years	21 years and over
	- - - - - - - - - - - - Percent[1]	- - - - - - - - - -		
Abies concolor	53(1)	0-6(3)	0-8(10)	6(1)
A. magnifica	--	24(1)	0-2(2)	--
A. nobilis	--	--	2(1)	--
Cedrus libani	48(1)	--	--	--
Chamaecyparis lawsoniana	--	--	0-13(2)	--
Cupressus arizonica	--	--	0-35(3)	--
C. bakeri	--	--	10(1)	--
C. forbesii	--	--	16(1)	--
C. goveniana	--	--	53(1)	--
C. lusitanica	--	--	--	10(1)
C. macnabiana	--	--	18(1)	--
C. nevadensis	--	--	18(1)	--
C. pygmaea	--	--	17-66(2)	--
C. sargentii	--	--	9-15(2)	--
Larix dahurica koreana	--	--	2(1)	--
L. occidentalis	--	--	5(1)	--
Libccedrus decurrens	74-98(2)	0(1)	0(1)	--
Picea sitchensis	--	68(1)	2-6(2)	--
Pinus attenuata	--	--	71-76(2)	--
P. brutia	8(1)	--	--	--
P. jeffreyi	76(1)	68-88(2)	51(1)	--
P. lambertiana	--	--	2-56(3)	0(1)
P. laricio var. salzmannii	--	--	1-6(2)	--
P. monticola	--	--	20-30(2)	--
P. ponderosa	61-86(2)	--	41-87(5)	--
P. radiata	94(1)	--	--	--
P. strobus	--	--	0(1)	--
P. thunbergii	--	--	8(1)	0(1)
P. torreyana	94(1)	--	--	--
Pseudotsuga taxifolia	--	66(1)	0-15(3)	--
Sequoia gigantea	--	58(1)	0-68(6)	--
S. sempervirens	2(1)	0(1)	0(6)	--
Tsuga heterophylla	--	--	1-13(2)	--
T. mertensiana	--	--	0-2(2)	0(1)

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[1] Numbers in parentheses indicate the number of seed lots represented.

Results

Seed of *Abies* and *Libocedrus* had low viability after 3 to 6 years in storage (tables 1 and 2). This agrees fairly well with previous reports[2] that seed of these genera lose most of their viability in the relatively short time of 4 to 5 years. One seed lot of *Abies concolor*, however, retained 53 percent viability after 3 years and two seed lots retained 6 to 8 percent after 16 and 21 years. Two seed lots of *Libocedrus decurrens* retained 98 and 74 percent viability after 2 and 3 years; however, all lots of this species stored for more than 8 years had lost all viability.

Seed of *Cupressus* and *Pinus* kept very well over a prolonged period. This was especially true of the closed-cone pines, *Pinus attenuata*, *P. radiata*, and *P. contorta*. Several seed lots of *P. attenuata* retained a viability of 71 to 87 percent after 16 to 17 years, and one seed lot of *P. radiata* still had a viability of 86 percent after 21 years, an indicated loss of only 8 percent. Several seed lots of *P. contorta*, stored for 16 and 17 years, had 40 to 47 percent viability. One seed lot of *P. contorta*, which had an original viability of 91 percent, lost only 14 percent during the first 11 years, but lost 30 percent during the next 6 years. Another seed lot, of the same species, had a viability of 58 percent at the end of 10 years, then dropped to 28 percent at 16 years. On the basis of these two seed lots, there is some indication that the rate of viability loss increases after 10 or 11 years. The various species of *Cupressus* (table 2) retained their viability for 11 to 21 years. The only exception was the seed lot collected in 1940, which had lost all viability in 11 years. Thi particular seed lot was believed to be immature when collected.

Not all species of the same genus store equally well. One of the best examples of this is in the genus *Sequoia*. *Sequoia gigantea* is generally known to retain its viability better than *S. sempervirens*. Two seed lots of *S. gigantea* still had 41 and 43 percent viability after 16 and 17 years. None of the seed lots of *S. sempervirens* had more than 1 percent viability at a comparable storage period. Another example is in the genus *Pseudotsuga*. One seed lot of *P. taxifolia* had a viability of 66 percent after 6 years and another had 31 percent after 16 years. None of the seed lots of *P. macrocarpa*, however, retained much viability after 4 years. One sample of the latter had 2 percent viability after 19 years.

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[2] Forest Service. 1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. 654. 416 p. illus.

The genera Chamaecyparis, Larix, and Tsuga were represented by only one or two species. In general, they had low viability after 15 years. One seed lot of Chamaecyparis lawsoniana and one of Tsuga heterophylla had 13 percent after 16 and 15 years respectively. The best result for Larix was for L. occidentalis which had 5 percent after 16 years. Very few reports on viability after prolonged storage are available for these genera.

In general, the results show that seed of most conifers can be collected in large quantities during good seed years with assurance that they will retain high viability for intervals sufficiently long to tide over the poor seed years--providing the seed is properly handled and stored.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 84 February 4, 1953

A TRIAL OF THREE CHEMICALS AS RODENT REPELLENTS IN DIRECT SEEDING[1]

G. H. Schubert, Forester,
Division of Forest Management Research

Sodium fluoroacetate (compound "1080") and, to a lesser extent, red lead and zinc phosphide, have been suggested for use as rodent repellents in direct seeding. On the basis of a small test in 1950 on the Stanislaus Experimental Forest in California, none of these chemicals appears effective as repellents even though all three are effective as poisons.

Compound "1080", equivalent to 5 percent by weight of the carrier, was added to asphalt and to dowax (a commercial preparation). Dowax was used as the carrier for zinc phosphide and for red lead, which were used at the rates of 5 and 10 percent by weight of the carrier, respectively. Water was added to each mixture to form a thin paste. Seeds were then rolled in the repellent and allowed to dry to facilitate handling and to insure maximum retention of the chemical.

A total of 464 spots were planted with sugar pine seed at the rate of 5 seed per spot. Approximately one-fifth of the seed spots were protected with cone screens to determine the effect of the chemical on germination. Untreated seeds were planted on one hundred unscreened spots.

None of the chemicals tested proved effective as repellents. Only 2 percent of the unscreened spots with coated seeds were stocked in the fall of the first year, and this dropped to 1 percent at the end of the second year (Table 1). In contrast, stocking on screened spots with coated seeds averaged 88 percent at the end of the first growing season, and 80 percent at the end of the second year. Results for the control seed spots were similar.

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[1] Mr. Joseph Keyes, retired, formerly Biologist, U. S. Fish and Wildlife Service, cooperated in the test by preparing the treated seed and helping with setting out of the seed spots.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

Table 1.--Percent of seed spots with one or more seedlings

Treatments	Stocked in 1950		Stocked in 1951	
	Screened	Unscreened	Screened	Unscreened
5 percent "1080" in asphalt	100	5	85	2
5 percent "1080" in dowax	85	0	80	0
5 percent zinc phosphide in dowax	80	0	80	0
10 percent red lead in dowax	93	2	71	2
Average, all coated seed	88	2	80	1
Control	80	4	75	2

Since rodents destroyed practically all seeds left unscreened, germination can be compared only on the screened seed spots. Seed treated with 5 percent "1080" in asphalt had the highest germination (54 percent). Those treated with 10 percent red lead in dowax had the lowest germination (43 percent). The untreated control seed germinated 48 percent. Those treated with 5 percent "1080" in dowax and with 5 percent zinc phosphide in dowax germinated 44 and 48 percent respectively. These differences are not statistically significant. The chemicals apparently neither repressed nor aided germination.

Empty seed coats, scattered in and around the seed spots indicated that rodents--white-footed mice (Peromyscus spp), chipmunks (Eutamias spp), and ground squirrels (Citellus spp)--and not birds had destroyed the seed. Evidently amounts of the coating substances too small to be repellent or lethal had been ingested by the rodents. A poison or repellent which could penetrate the seed coat and be absorbed in the endosperm without being detrimental to the embroyo would probably be a more effective means of rodent control. The substance, Tetramine, under current investigation by the U. S. Fish and Wildlife Service[2], is believed to possess these properties. Tetramine is currently being tested by the California Forest and Range Experiment Station in the Douglas-fir area in California.

2/ Spencer, Donald A. and Nelson B. Kverno. 1952. Research in rodent control to promote reforestation by direct seeding. U. S. Fish and Wildlife Service. Progress Report No. 3, 74 p.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 85 March 3, 1953

FORESTRY DEPA
UNIVERSITY OF THE SOU

PINE POLLEN COLLECTION DATES - ANNUAL AND GEOGRAPHIC VARIATION[1]

By J. W. Duffield

Activity in pine breeding has increased throughout the temperate forest regions of the world since the Institute of Forest Genetics issued its first summary of pollen collection dates in 1947. Cooperation between pine breeders has increased at the same time. The information most essential for conducting cooperative breeding operations are the dates of pollen collection (which also approximate the dates at which the bagging of flower buds to control pollination should be done) for various species at various localities. This publication, adding four years' data to the note issued in 1947, covers a period of 14 years. In addition, some data are presented on the relation between temperature and development of catkins and on the effect of altitude on time of pollen collection. These new data, although still fragmentary, should assist workers elsewhere to generalize from the data collected at the Institute of Forest Genetics.

Some notes on the pollen collection techniques used at the Institute of Forest Genetics[2] should help in the interpretation of the data which follow. Catkins, or twig-tips bearing catkins, are picked when the first catkins on a tree are starting to open. Thus a collection date usually corresponds rather closely to the date on which pollen shedding starts. The collection date also corresponds to a date five days to a week later than that on which bagging of conelet buds on the same tree would be advisable. Complete extraction of the pollen requires from one to five days or rarely longer. If the pollen has been extracted under conditions of low

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[1] A revision of Duffield, J. W. 1947. Dates and places of pollen collection by the Institute of Forest Genetics. Calif. Forest and Range Exp. Sta. Research Note No. 54. 5 p.

[2] Cumming, W. C., and F. I. Righter. 1948. Methods used to control pollination of pines in the Sierra Nevada of California. U. S. Dept. Agr. Cir. No. 792. 18 p.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

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humidity (from 15 to 30 percent relative humidity) it should be a highly "fluid" dust. Otherwise it is advisable to reduce its moisture content by holding it in a desiccator over anhydrous calcium chloride for one to two days. If this is not done, the mold spores germinate (these spores cannot be eliminated from pollen samples by present methods). Then the pollen sample becomes felted into a lumpy mass by the growth of mold mycelia. Such pollen is of little or no value for controlled pollinations.

Combining the time required for extraction and desiccation, it is usually possible to ship pine pollen from one to seven days after it is collected. The extraction techniques used at the Institute of Forest Genetics[2] result in pollen samples of high purity (with the exception of mold spores) in spite of the fact that the pollen parents are almost invariably surrounded by many other pines of the same or different species, many of which are shedding pollen freely at the time when catkins are collected.

Pressure of work during the pollination season seldom permits tests of pollen germinability immediately following pollen extraction. Much reliance is placed on the physical properties of the pollen. If it is dry enough to act like a fluid, and no more than one year old, pollen is usually highly germinable. Most pine pollen shows high germinability for many months following extraction if: (1) extraction humidity has been low enough to prevent molding of the pollen; (2) pollen has been stored at 25 percent to 50 percent relative humidity at a temperature below 5°C (41°F).[3]

Table 1 has been compiled from the past 14 years' breeding records of the Institute of Forest Genetics. So far, systematic and comprehensive phenological records have not been kept. For this reason, data for many of the pines and other trees growing in the Eddy Arboretum[4] at Placerville are lacking.

The trees in the Eddy Arboretum are derived from trees growing in many parts of the Northern Hemisphere. When known with any degree of certainty, the original sites of trees from which pollen producers were derive are given in Table 1. Pollen of some species is collected from "wild" tree growing at the original site. Pollen of other species is collected from trees growing in the Eddy Arboretum near Placerville, at Berkeley, and at Fresh Pond, California.

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[3] Duffield, J. W., and A. G. Snow, Jr. 1941. Pollen longevity of *Pinus strobus* and *Pinus resinosa* as controlled by humidity and temperature. Amer. Jour. Bot. 28: 175-177.

[4] Weidman, R. H. 1947. Trees in the Eddy Arboretum. Calif. Fores and Range Exp. Sta. Research Note No. 53. 8 p.

The table column showing the number of years in which pollen was collected is a rough index of reliability.

Figure 1 summarizes the dates of pollen collection for the fourteen pine species and hybrids from which pollen has been collected for five or more years in the Eddy Arboretum. The horizontal lines extend from the earliest to the latest collection date for each species, and the vertical bars near the center of each line indicate the mean collection dates. At the earliest and latest end of each line is indicated the year in which the record for earliness or lateness for the species was made. It will be noted that, generally, 1947 was a year of early pollen shedding, while 1948 was a year of late shedding. However, the data for P. radiata are exceptional; 1948, with high January and February temperatures but low temperatures from March through June, produced the earliest record for P. radiata pollen shedding.

Figure 2 is an attempt to relate pollen shedding dates to temperature. Three years were selected for study: 1947, a year of early shedding; 1948, a year of late shedding, and 1949. Pollen collection dates were recorded for 5 representative species and hybrids for each of these 3 years. From thermograph records, corrected by semi-weekly thermometric readings, mean daily temperatures were computed. These are plotted for the period March 1 through June 21 for each of the 3 years. To establish a "normal" curve of mean daily temperatures, the following procedure was followed. Mean daily temperatures for the periods 1929-1937, inclusive[5], and 1947-49, inclusive, were averaged for the period March 1 through June 21. These averages were then smoothed by means of computing 7-day moving averages. Finally, a free-hand curve was fitted to these averages. The resulting curve, of doubtful climatological value, has the advantage of furnishing a suggestive standard for comparing the course of temperatures in different years. This "normal" curve is plotted with the mean daily temperature for each of the 3 years. It is obvious that, for the period studied, 1948, the year of late pollen shedding, was abnormally cold, whereas 1947 was distinctly warmer. The spring of 1947 started cool and approached normal as the season progressed. Pollen shedding dates are quite consistent with these curves, with the exception of the early shedding of X P. attenuradiata pollen in 1948. This is no doubt a result of the relatively high January - February temperatures in 1948. The late shedding of pollen by this hybrid in 1949 appears to be the consequence of low temperatures in February.

One further generalization can be made from the data on hand. Pinus ponderosa, on the west slope of the Sierra Nevada, grows from 125 to 7,000 feet above sea level. Pollen collection dates for trees from 1,000 to 6,000 feet elevation have been recorded. From these data a mean interval of 8 days per 1,000 feet difference in elevation has been computed. This figure agrees moderately well with Hopkins'[6] constant of 4 days for each 400 feet difference in elevation.

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[5] Mirov, N. T. 1939. Climatological observations at the Institute of Forest Genetics, Placerville, California, from 1929 to 1937. Unpublished manuscript, Calif. Forest and Range Exp. Sta.

[6] Hopkins, A. D. 1918. The bioclimatic law. U. S. Dept. Agr. Weather Bureau; Monthly Weather Review - Supplement No. 9. pp. 1-42.

Table 1.--Dates of pine pollen collection by the Institute of Forest Genetics

O, indicates pollen-producing trees growing at original site;
E, at Eddy Arboretum, Placerville, California, Lat. 39°N, Long. 121°W, Alt. 2700 feet;
B, at Berkeley, California, Lat. 38°N, Long. 122°W, Alt. 200 feet; and
F, at Fresh Pond, California, Lat. 39°N, Long. 121°W, Alt. 3700 feet.

Species	Original site			Growing at	Pollen collection dates			No. of years
	Lat. (N)	Long.	Altitude (feet)		Earliest	Latest	Mean	
Pinus:								
albicaulis Engelm.	39	120W	8,900	O	-	-	July 23	1
apacheca (see P. latifolia)								
aristata Engelm.	35	115W	10,000	O	June 30	July 26	July 18	3
arizonica Engelm.	32	109W	-	E	Apr. 15	May 13	Apr. 29	5
do.	32	109W	-	O	-	-	May 22	1
Armandi Franch.	-	-	-	E	Apr. 25	May 25	May 11	8
attenuata Lemm.	39	121W	3,000	O	Mar. 20	Apr. 27	Apr. 10	4
do.	38	122W	2,000	O	-	-	Mar. 8	1
do.	39	121W	-	E	-	-	Apr. 19	1
do.	39	121W	-	F	-	-	Apr. 20	1
x attenuradiata Stockwell & Righter	-	-	-	E	Mar. 12	Apr. 15	Mar. 21	7
attenuata X attenuradiata	-	-	-	E	-	-	Apr. 21	1
ayachuite var. brachyptera Shaw	32	109W	-	O	-	-	May 22	1
do.	32	109W	-	E	May 25	June 1	-	2
Balfouriana Balf.	37	117W	10,000	O	July 12	July 27	July 20	3
Banksiana Lamb.	-	-	-	E	Mar. 20	Apr. 27	Apr. 14	10
do.	44	89W	-	O	-	-	May 24	1
Bungeana Zucc.	32	119E	-	E	Apr. 24	May 24	May 9	2
canariensis C. Smith	28	16W	-	E	-	-	May 3	1
do.	28	16W	-	B	Mar. 15	Apr. 10	Mar. 31	3
caribaea Morelet	-	-	-	E	-	-	Mar. 31	1
contorta	39	124W	-	O	-	-	June 9	1
do.	41	124W	-	E	-	-	May 11	1
contorta var. bolanderi Parl.	39	124W	-	O	-	-	June 9	1

Species	Original site			Growing at	Pollen collection dates			No. of years
	Lat. N.	Long.	Altitude feet		Earliest	Latest	Mean	
contorta var. latifolia Engelm.	39	120W	6,000	O	June 5	July 8	June 22	3
do	39	120W	7,000	E	Apr 19	May 11	May 1	4
do	49	115W	-	E	Apr 9	May 6		2
do.	51	119W	1,000	E	Apr 14	May 7	Apr 26	4
contorta var. latifolia x Banksiana	-	-	-	E	Apr 11	May 7	Apr 24	6
Coulteri D. Don	33	117W	-	E	Apr 21	May 15	-	2
do	34	116W	5,000	O	-	-	June 8	1
do	37	121W	4,000	O	-	-	June 5	1
do	38	122W	2,000	E	Apr 25	May 26	May 15	5
echinata Mill.	33	93W	-	E	Apr [illegible]	Apr 23	Apr 11	3
do	31	93W	-	E	-	-	May 9	1
echinata x caribaea	-	-	-	E	Apr 14	Apr 18		2
echinata x taeda	-	-	-	E	Mar 31	May [illegible]	Apr 19	5
excelsa (see P. griffithi)								
flexilis James	-	-	-	E	May 8	June 7	May 24	5
do.	37	118W	9,000	O	-	-	July 16	1
glabra Walt.	-	-	-	E	-	-	Apr 15	1
griffithi McClell.	27	81E	-	E	Apr 2[illegible]	June 3	May 17	8
halepensis Mill.	-	-	-	E	Apr 15	Apr 19	-	2
halepensis var. brutia Elw. & Henry	-	-	-	E	-	-	Apr 21	1
jeffreyi Grev. & Balf	34	116W	5,000	O	-	-	June 8	1
do	37	121W	4,000	O	May 21	June 5	-	2
do	39	120W	5,000	O	-	-	June 21	1
do.	39	120W	6,000	O	June 12	June 26	June 18	5
do	39	120W	7,000	O	June [illegible]	July 1	June 25	3
do	40	121W	[illegible],000	O	-	-	June [illegible]	1
jeffreyi x Coulteri	34	116W	5,000	O	June 4	June 6	June 5	3
do	37	121W	4,000	O	May 21	June 9		2
do.	33	117W	-	O	-	-	June 7	1
jeffreyi x ponderosa	-	-	-	F	-	-	May 28	1
Lambertiana Dougl.	34	116W	[illegible],000	O	-	-	June 8	1
do	39	120W	[illegible],000	O	-	-	July 8	1
do	39	120W	6,000	O	July 1	July 9	July 6	4
do	-	-	-	E	May 21	May 31	May 27	3

Species	Original site			Growing	Pollen collection dates			No. of
	Lat. (N)	Long.	Altitude (feet)	at	Earliest	Latest	Mean	years
latifolia Sarg.	32	109W	-	0	-	-	May 24	1
do.	32	110W	-	E	Apr. 25	June 1	May 16	6
leiophylla Schl. & Cham.	-	-	-	E	-	-	May 20	1
longifolia (see P. roxburghii								
massoniana Lamb.	-	-	-	E	-	-	Apr. 19	1
monophylla Torr.	37	118W	-	E	-	-	June 2	1
Montezumae Lamb.	-	-	-	E	Apr. 21	May 5	Apr. 26	4
monticola Dougl.	39	120W	7,000	0	June 8	Aug. 5	July 11	7
do.	48	114W	-	E	May 8	June 2	-	2
do.	47	116W	3,000	0	-	-	July 2	1
do.	46	121W	-	E	-	-	May 29	1
muricata D. Don	34	120W	-	E	Apr. 7	Apr. 20	-	2
muricata var. borealis Duffield	39	124W	-	0	-	-	Apr. 19	1
nigra var. austriaca Asch. & Graeb.	-	-	-	E	Apr. 29	May 10	Apr. 30	3
nigra var. calabrica Schneid.	-	-	-	E	May 5	May 12	May 9	3
nigra var. cebennensis Rehder	44	4E	-	E	-	-	May 14	1
patula Schl. & Cham.	-	-	-	E	Mar. 20	Apr. 25	Apr. 11	3
pinaster Ait.	-	-	-	E	Apr. 1	Apr. 25	Apr. 14	5
pinea L.	-	-	-	E	Apr. 30	May 20	-	2
ponderosa Laws.	35	112W	-	E	-	-	May 27	1
do.	37	122W	0	0	-	-	May 8	1
do.	37	122W	0	E	-	-	May 6	1
do.	39	123W	2,000	E	-	-	May 16	1
do.	39	121W	1,000	0	-	-	May 2	1
do.	39	121W	2,000	0	Apr. 21	May 14	May 4	4
do.	39	121W	3,000	0	Apr. 15	May 28	May 11	7
do.	39	121W	4,000	0	Apr. 25	May 30	May 21	2
do.	39	120W	5,000	0	June 3	June 11	June 6	2
do.	39	120W	6,000	0	June 14	June 27	June 20	2
do.	42	121W	-	E	-	-	May 26	1
do.	42	123W	-	E	-	-	May 27	1
do.	42	124W	-	E	-	-	May 5	1
do.	43	122W	-	E	-	-	May 2	1
do.	46	114W	4,000	E	-	-	May 3	1
do.	47	121W	2,000	E	-	-	May 4	1

Species	Original site			Growing at	Pollen collection dates			No. of years
	Lat. (N)	Long.	Altitude (feet)		Earliest	Latest	Mean	
ponderosa var. scopulorum Engelm.	37	113W	-	E	-	-	Apr. 18	1
do.	40	105W	-	O	-	-	May 25	1
do.	40	107W	-	O	-	-	May 24	1
do.	42	107W	-	E	Apr. 16	Apr. 28	-	2
do.	43	99W	-	E	Apr. 16	May 14	Apr. 29	5
pungens Lamb.	40	78W	-	E	Mar. 25	Apr. 25	Apr. 12	4
quadrifolia Sudw.	33	117W	-	E	-	-	June 9	1
radiata D. Don	34	122W	0	E	Jan. 28	Apr. 12	Mar. 13	7
do.	34	122W	0	F	Apr. 19	Apr. 24	-	2
resinosa Ait.	-	-	-	E	Apr. 17	May 10	Apr. 26	6
rigida Mill.	-	-	-	E	Apr. 8	Apr. 29	Apr. 17	4
rigida x taeda	-	-	-	E	Mar. 26	Apr. 17	Apr. 8	3
Roxburghii Sarg.	-	-	-	E	Mar. 6	Mar. 30		2
Sabiniana Dougl.	39	121W	3,000	O	Mar. 24	Apr. 28	Apr. 18	4
do.	39	121W	3,000	F	-	-	Apr. 20	1
Sinensis Lamb.	-	-	-	E	-	-	Apr. 28	1
Sinensis var. yunnanensis Franch.	-	-	-	E	-	-	Apr. 24	1
x Sondereggeri H. H. Chapman	-	-	-	E	Mar. 22	Apr. 5	Mar. 29	2
strobus L.	44	72W	-	E	May 2	June 8	May 20	5
sylvestris L.	-	-	-	E	Apr. 18	May 23	May 1	5
tabulaeformis Carr.	-	-	-	E	-	-	Apr. 14	1
taeda L.	-	-	-	E	Mar. 23	May 10	Apr. 12	9
taeda x caribaea	-	-	-	E	-	-	Apr. 3	1
taiwanensis Hayata	-	-	-	E	-	-	Apr. 25	1
Thunbergii Parl.	-	-	-	E	Apr. 8	May 4	Apr. 20	3
Torreyana Parry	33	117W	0	E	Feb. 25	Apr. 5	Mar. 20	4
do.	33	117W	0	B	Feb. 20	Mar. 30	Mar. 5	3
virginiana Mill.	-	-	-	F	-	-	May 8	1
do.	-	-	-	E	Apr. 11	Apr. 23	Apr. 19	3
washoensis Mason & Stockwell	39	120W	8,000	O	June 13	July 12	July 2	4

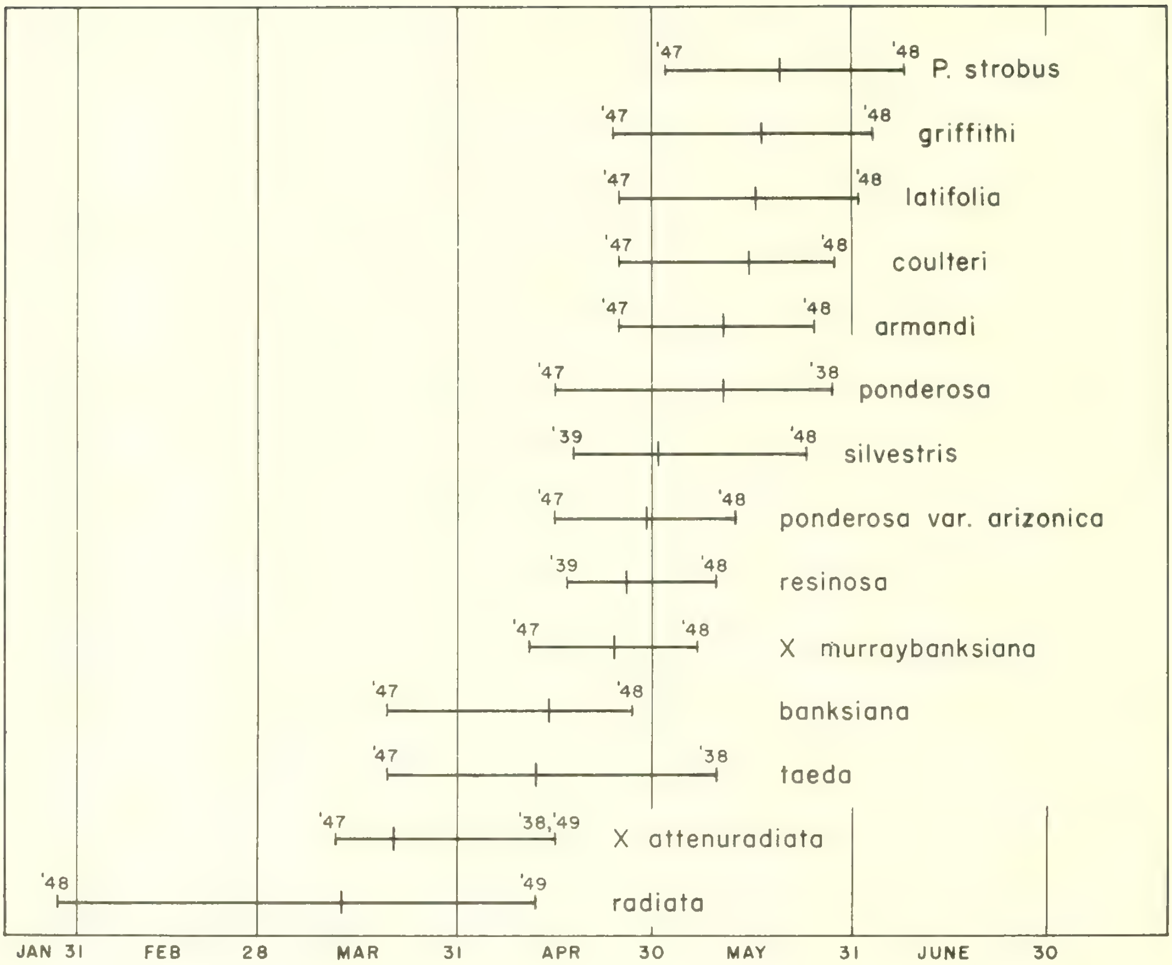

Figure 1.- Pollen collection dates for species collected for five or more years in the Eddy Arboretum.

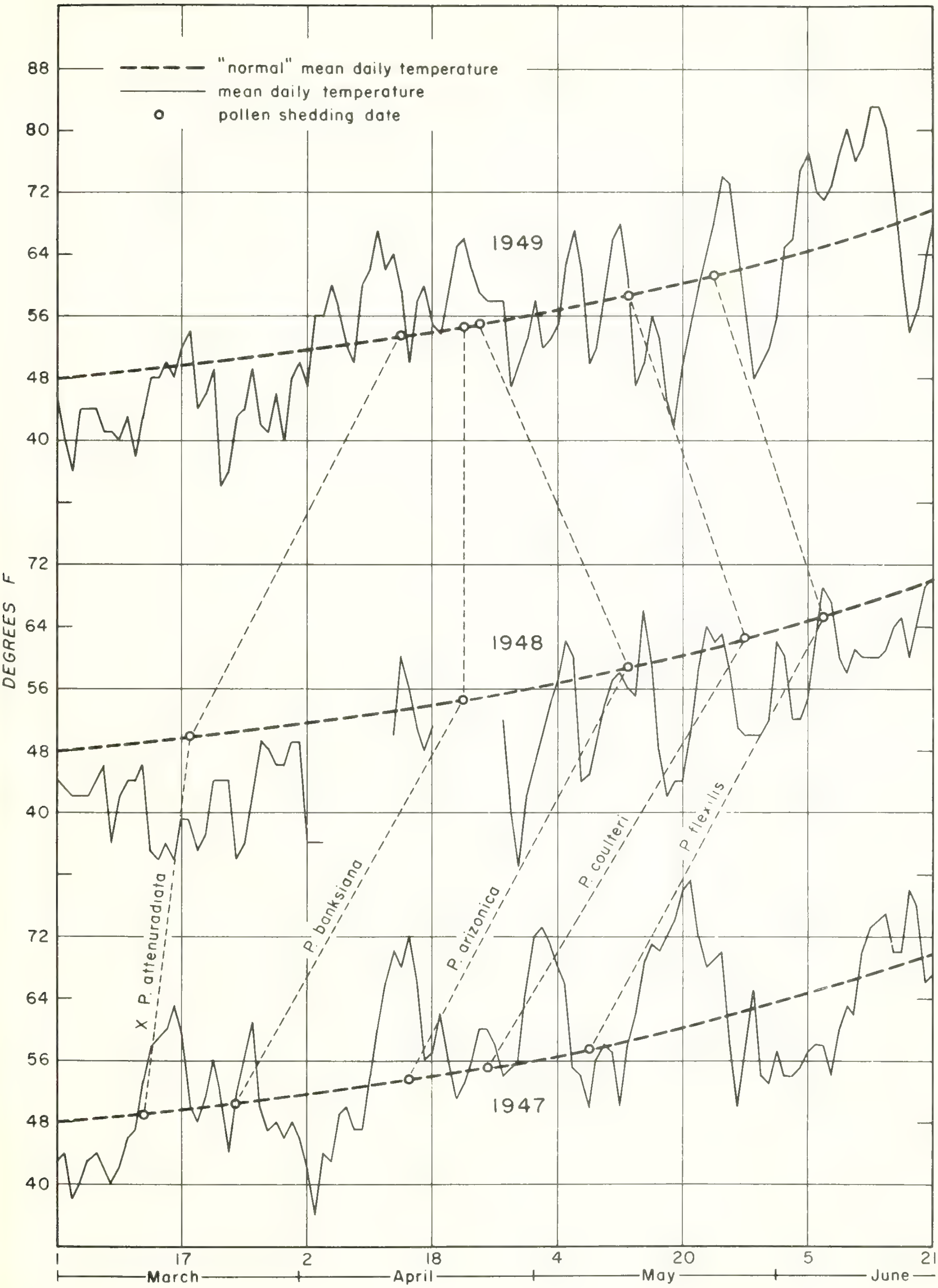

Figure 2.- Pollen shedding dates and mean daily temperatures in 1947, 1948, and 1949; and "normal" mean daily temperatures (see page 3 for derivation of normal curves).

FOREST RESEARCH NOTES
U.S. DEPARTMENT OF AGRICULTURE
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CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
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FORESTRY DEPARTMENT
UNIVERSITY OF

ANNOTATED LIST OF PINE HYBRIDS MADE AT THE INSTITUTE OF FOREST GENETICS

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Pine hybrids produced up to 194[illegible] at the Institute of Forest Genetics were listed in a recent publication to acquaint plant breeders and biologists with the progress of the hybridization work (7)[1]. Numerous requests for information about pine hybrids indicate that a different type of publication on the pine hybridization program is needed; namely, a list of the hybrids by common names of their parental species, giving a digest of our present knowledge obtained from results of tests conducted at the Institute and elsewhere and our surmises about the regions where the hybrids may be of value. This paper is directed at that need.

Most plant hybrids can be expected to be intermediate between their parent species in most quantitative characters. Sometimes hybrids resemble one parent in a certain character, such as resistance to the pine reproduction weevil which the Jeffrey-Coulter pine hybrid inherits from Coulter pine (4). Less frequently, a hybrid may exceed both parents in rate of growth or some other quantitative character. This phenomenon is known as hybrid vigor. Even the truly intermediate hybrid may have some advantages. It may, for example, be able to tolerate the adverse climate to which its slower-growing parent is adapted and in which its faster-growing parent cannot survive. Thus almost any hybrid has potential value and merits at least small-scale testing in the appropriate regions.

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[1] Numbers in parentheses refer to bibliography at end of paper.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

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Suggestions given here on geographic and climatic adaptability should be recognized merely as suggestions. They are often based not on actual trials or careful studies of comparative climatology, but on information about adaptation of pine species in various parts of the world gleaned from the literature and from conversations with visiting foresters from virtually every major coniferous forest region of the world.

With regard to the availability of hybrid seed for testing or large scale planting by others, some explanation of the Institute's situation and policies is necessary. The Institute wishes to get comprehensive information on the economic possibilities of the hybrids which perform well at Placerville. This information would in the future enable the Institute and other breeding agencies to breed for specific purposes with greater precision than would otherwise be possible. Such information can be obtained only from tests established on suitable sites in various regions in the United States and in foreign countries by cooperators having the knowledge, facilities, and resources requisite for properly conducting the tests. This means that the objectives and methods must be clearly understood and agreed to in advance; that the cooperator must have both control over the area involved and the personnel and means with which to maintain the test and obtain the desired data on performance. As research institutions are best qualified in those respects, the Institute favors them as cooperators; and accordingly most of its cooperative field tests are being conducted by other Forest Service experiment stations and by other research and educational institutions. Wood-using and timber-growing industries and other private parties having the requisite resources are welcomed as cooperators when seed is available. No administrative procedure has been set up to enable the Institute to make its products available for other than scientific purposes, except to the U. S. Forest Service.

Unless otherwise stated, all tests so far made, have been conducted at the Institute of Forest Genetics at Placerville, California, latitude 39° north, longitude 121° west, altitude 2700 feet above sea level. Temperature and precipitation data are as follows:

Temperature and Precipitation

Institute of Forest Genetics

Month	Max. temp. 1929-37	Mean temp. 1929-37	Min. temp. 1929-37	Precipitation 1930-37	Snowfall 1928-37
	°F.	°F.	°F.	Inches	Inches
January	48.8	41.6	34.5	7.36	14.40
February	53.4	45.1	36.9	7.02	1.54
March	59.5	50.1	40.7	4.42	0.63
April	63.9	53.8	43.7	3.02	-
May	71.8	60.5	49.5	1.60	-
June	80.6	68.3	56.0	0.87	-
July	90.7	77.5	64.3	0.01	-
August	89.8	77.2	64.7	-	-
September	82.0	69.8	57.6	0.26	-
October	72.6	62.0	51.5	2.05	-
November	61.6	52.5	43.8	3.24	0.61
December	53.0	45.5	37.9	6.05	5.51
Year	69.0	58.7	48.4	35.90	22.70

The outstanding features of this climate are long dry summer, mild rainy winter, and occasionally 20 inches or so of heavy, wet snow which damages certain of the introduced pines. The soil at the Institute, Aiken clay loam, has a rather high moisture-holding capacity, and despite the long summer drought, moisture is available to tree roots in the lower horizons. Pot culture tests have shown that the levels of available phosphorus and nitrogen in Aiken clay loam are rather low. The conifers growing spontaneously at the Institute are *Pinus ponderosa* Laws., *P. sabiniana* Dougl., *P. lambertiana* Dougl., *Pseudotsuga taxifolia* (Poir.) Britton, and *Libocedrus decurrens* Torr.

In the annotated list which follows, the name of the seed-parent species is given first, the pollen parent second. English names are those given in Standardized Plant Names (3). The year-date which follows is the year in which the cross was first successfully made at the Institute. The list is not a complete catalogue of hybrids produced at the Institute of Forest Genetics (hereafter abbreviated as IFG)--some hybrids unlikely to have practical value are omitted.

1. KNOBCONE x MONTEREY (*P. attenuata* Lamm. x *radiata* D. Don). 1927.

Described as x *P. attenuradiata* Stockwell and Righter (9). Occurs spontaneously in Santa Cruz County, California. The cross made at IFG utilized the economically-unimportant Sierra foothill race of knobcone pine, which is more cold-resistant but less vigorous than Monterey pine and the coastal forms of knobcone pine. Hybrid is intermediate between the parents in growth-rate, cold-resistance, stem-form, and flowering-time (9).

Should be tested up to 3,000 feet on the west slope of the Sierra Nevada against ponderosa pine, and its more promising hybrids and against other commercially important species of forest trees. At IFG the Monterey-knobcone hybrid appears to outgrow ponderosa pine by at least 10 percent in height and diameter up to 23 years (present age of oldest hybrids). Should also be tested up to 3,000 feet in the Coast Ranges on ponderosa pine and Douglas fir sites. Should be of value on colder margins of areas where Monterey pine is grown successfully (e.g. Australia, New Zealand, South Africa, Spain, Portugal, Chile, Argentine).

Wood tested at Forest Products Laboratory (1) was roughly comparable to that of ponderosa pine in density and longitudinal shrinkage.

2. KNOBCONE x BISHOP (*P. attenuata* x *muricata* D. Don). 1946.

In early tests at IFG appears to outgrow both parents. Stem form unknown. No recommendations for use can be made at present.

3. SHORE (closely related to lodgepole pine) x JACK (*P. contorta* Dougl. x *banksiana* Lamb.). 1946.

In early tests at IFG outgrows shore pine and equals jack pine. Depending on development of market for shore pine as source of pulpwood, this may be of value in coastal Oregon, Washington, and British Columbia; possibly also in British Isles, coastal Norway, and Belgium. Stem form unknown.

4. LODGEPOLE x JACK (*P. contorta* var. *latifolia* Engelm. x *banksiana*). 1939.

Occurs spontaneously in Alberta (5). Described as x *P. murraybanksiana* Righter and Stockwell (6). In tests at IFG, central Wisconsin, northern Idaho, and eastern Massachusetts, outgrows California lodgepole in height and diameter. Early growth about equal to that of jack pine, but in several localities, after several years, the jack pine falls behind the hybrid. Produces cones in third or fourth year. Should be valuable for pulpwood production. Should be tested in Pacific Northwest, northern Rocky Mountains, Lake States, northern New York, New England, and Ontario, Quebec, and Maritime Provinces of Canada. Likewise in British Isles, northern Europe, northeast Asia, and those parts of Australia and New Zealand where lodgepole pine has been successful.

5. SANTA CRUZ ISLAND x MONTEREY (P. remorata Mason x radiata). 1942.

Grows at about the same rate as both parent species. Has good form. This hybrid should be tested as a potential replacement or alternative type wherever Monterey pine is used. Tests should include resistance to insects such as Sirex noctilio, spider mites, and other pests which, in certain localities, impair the productivity of Monterey pine.

6. JEFFREY x COULTER (P. jeffreyi Grev. & Balf. x coulteri D. Don). 1944.

Occurs spontaneously wherever parent species occur together. In tests at IFG outgrows Jeffrey pine and is somewhat slower growing than Coulter pine. So far, this cross has yielded very low proportions of sound seeds. Therefore, the backcross hybrid listed below is considered of greater practical importance.

7. JEFFREY x (JEFFREY-COULTER) (P. jeffreyi x (jeffreyi x coulteri)). 1939.

Pollen from a natural hybrid (10). Yields of seed of this backcross are very high. Cage-tests at IFG suggest that this hybrid is more resistant than Jeffrey pine to the pine reproduction weevil which has caused high mortality in plantations of Jeffrey and ponderosa pines in northern California. Preliminary results of uncaged tests in localities in northern California, where the insect abounds, give weight to the suggestion. The hybrids grow at approximately the same rate as ponderosa pine, and have equally good stem form and branching habits. In view of the susceptibility of ponderosa pine to the pine reproduction weevil, these circumstances combine to make this backcross the most promising hybrid yet produced for use in the California region. It is therefore being tested, under field conditions, throughout the California pine region. It may not offer any advantage, however, in comparison with ponderosa pine in regions not infested with the pine reproduction weevil.

8. PONDEROSA x APACHE (P. ponderosa x latifolia Sarg.). 1943.

This hybrid outgrows both parent species, and is of great promise for use in the California pine region, and perhaps in southwestern U.S. and northern Mexico. It is susceptible to attacks of the pine reproduction weevil but, due to its greater vigor, it outgrows susceptibility to the insect more quickly than does ponderosa pine. Nevertheless, steps are being taken to introduce reproduction weevil resistance from Coulter pine.

9. PONDEROSA x ARIZONA (P. ponderosa x ponderosa var. arizonica (Engelm.) Shaw). 1946.

This hybrid slightly outgrows ponderosa in height. Its early performance in plantations at 6,000 feet on the Stanislaus National Forest in California is excellent. It should be tested throughout the California pine region, in southwestern U.S., and in northern Mexico.

10. PONDEROSA x MONTEZUMAE (P. ponderosa x montezumae Lamb.). 1946.

In nursery tests at Placerville, this hybrid outgrows ponderosa in height. It should be tested throughout the California pine region, in southwestern U.S., and in northern Mexico.

11. COASTAL PONDEROSA x ROCKY MOUNTAIN PONDEROSA (P. ponderosa x ponderosa var. scopulorum Engelm.). 1941.

The hybrid outgrows the Rocky Mountain variety and equals the coastal and Sierra Nevada forms in tests at IFG. It may, therefore, merit trial in the Rocky Mountain and Black Hills regions where its cold-hardiness must be tested.

12. SHORTLEAF x SLASH (P. echinata Mill. x caribaea Morelet). 1931.

In tests at IFG appears to have narrower crown and finer branches than shortleaf. Potential value seems to be in putting a faster growing, better formed tree on shortleaf pine sites to the north and west of natural distribution of slash pine. May prove to have some value in developing a pine more resistant to fusiform rusts than slash pine, in which case it may be of importance in the general range of slash pine. Should be tested in areas to north and west of natural distribution of slash pine.

13. SHORTLEAF x LOBLOLLY (P. echinata x taeda L.). 1933.

According to unpublished observations, occurs spontaneously in east Texas and perhaps elsewhere. In tests at IFG outgrows shortleaf in height and diameter by about 10 percent, and has shown great resistance to cold in southern Illinois. May be of value on shortleaf sites. Should be tested throughout natural distribution of shortleaf pine.

14. PITCH x LOBLOLLY (P. rigida Mill. x taeda). 1933.

This hybrid grows faster and has better form than pitch pine but in tests in Maryland has seemed inferior to loblolly. It has outgrown loblolly pine in New Jersey, and shortleaf pine in southern Illinois where it appears to be more frost resistant than both loblolly and shortleaf pine. It should be tested north of the distribution range of loblolly pine in pitch pine areas, and in Illinois where it may produce a tree of better form and faster growth than pitch pine.

15. LOBLOLLY x SLASH (P. taeda x caribaea). 1931.

In small test at IFG, this hybrid appears to have somewhat better form than loblolly. May be valuable in bringing a better-formed, faster-growing tree into the loblolly region, and in breeding a slash pine more resistant to fusiform rust. Should be tested throughout the loblolly pine region.

16. SUGAR x ARMAND'S (P. lambertiana x armandi Franch.). 1947.

Yields of seed following this cross are very low. Nevertheless, as Armand's pine is highly resistant to blister rust, this hybrid may be of value in developing blister-rust-resistant sugar pine. The first tests will be inoculation or exposure tests to determine the degree of blister-rust resistance of this hybrid.

17. SUGAR x KOREAN (P. lambertiana x koraiensis Sieb. & Zucc.). 1947.

This cross, likewise, is difficult to make; so far only one seedling has been produced. As Korean pine is highly resistant to blister rust, this hybrid should also be of value in developing blister-rust-resistant sugar pine, and promises to be more cold resistant than the sugar x Armand's hybrid.

18. WESTERN WHITE x EASTERN WHITE (P. monticola Dougl. x strobus L.). 1939.

This hybrid is of special interest because it has outgrown both parent species in numerous tests made at IFG. Several geographic races of both parent species have been used in this cross, always resulting in vigorous hybrids. Therefore, this hybrid should be tested throughout the distribution ranges of both parent species. The finding in both species of individuals which are apparently resistant to blister rust (2), (8), inspires hope that vigorous resistant hybrids will soon be produced.

19. WESTERN WHITE x HIMALAYAN WHITE (P. monticola x griffithi McClell.). 1942.

This hybrid outgrows western white pine and appears to be less susceptible to blister rust than that species. The hybrid grows at about the same rate as Himalayan white pine, but is more drought resistant. The hybrid should be tested throughout the distribution range of western and eastern white pines, but may not be completely cold hardy in the colder parts of these regions.

20. WESTERN WHITE x BALKAN WHITE (*P. monticola* x *peuce* Griseb.). 1947.

This hybrid grows no faster than western white pine but may combine cold hardiness and moderate resistance to blister rust. Tests of its susceptibility to blister rust must precede tests of its growth in the field.

21. WESTERN WHITE x (BALKAN WHITE x EASTERN WHITE) (*P. monticola* x (*peuce* x *strobus*)). 1946.

This hybrid grows at about the same rate as the vigorous wester white x eastern white hybrid. Its value will depend on the outcome of blister-rust-resistance tests.

22. LIMBER x HIMALAYAN WHITE (*P. flexilis* James x *griffithi*). 1947.

In early test at IFG outgrows limber pine by 100 percent in height. Should be of value as a blister-rust-resistant ornamental white pine with greater cold resistance than Himalayan white pine. Should be tested for both rust and cold resistance. Value as a timber tree cannot yet be estimated, but its rate of growth is extremely rapid for white pine.

23. EASTERN WHITE x HIMALAYAN WHITE (*P. strobus* x *griffithi*). 1940.

This hybrid has shown good resistance to blister rust in a rigorous exposure test in Oregon. It outgrows eastern white pine and is about equal to Himalayan white and should be tested in the distribution ranges of eastern and western white pines as well as in those parts of Europe where the good growth of eastern white pine is offset by its blister rust susceptibility.

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FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 87 September 25, 1953

EFFECTS OF GROUND COVER AND CLASS OF PLANTING STOCK ON SURVIVAL OF TRANSPLANTS IN THE EASTSIDE PINE TYPE OF CALIFORNIA

By

D. F. Roy

When the forester finds planting necessary to regenerate an area he should know which species and class of planting stock is best suited to his particular operation. He should also weigh the expected successes on various locations which could be planted. Through such a procedure the best planting locations will be given priority and the best results, measured by survival and growth, will be obtained from the efforts expended. A test conducted at the Blacks Mountain Experimental Forest, an area typical of the California eastside pine type, has shown that survival of ponderosa pine (Pinus ponderosa Laws.) and Jeffrey pine (P. jeffreyi Grev. and Balf.) planting stock is strongly affected by the vegetation, logging slash, and stoniness of the ground at the points where the trees are planted.

In this experiment 1,200 trees were planted in the spring of 1951 on recently cutover land of various aspects. An equal number of ponderosa pine and Jeffrey pine were planted, half of each species being 1-0 and half 1-1 nursery stock. In planting, the trees were spaced 6 x 6 feet in a randomized block design. This note reports the results after two years.

Survival by Species and Classes of Planting Stock

Survival rates for the various types of planting stock were considerably different, becoming greater with time (figure 1 and following tabulation).

Planting stock		Percent survival	
		First year	Second year
Ponderosa pine	1-1	67	60
Jeffrey pine	1-1	52	47
Jeffrey pine	1-0	48	39
Ponderosa pine	1-0	42	30
All		52	44

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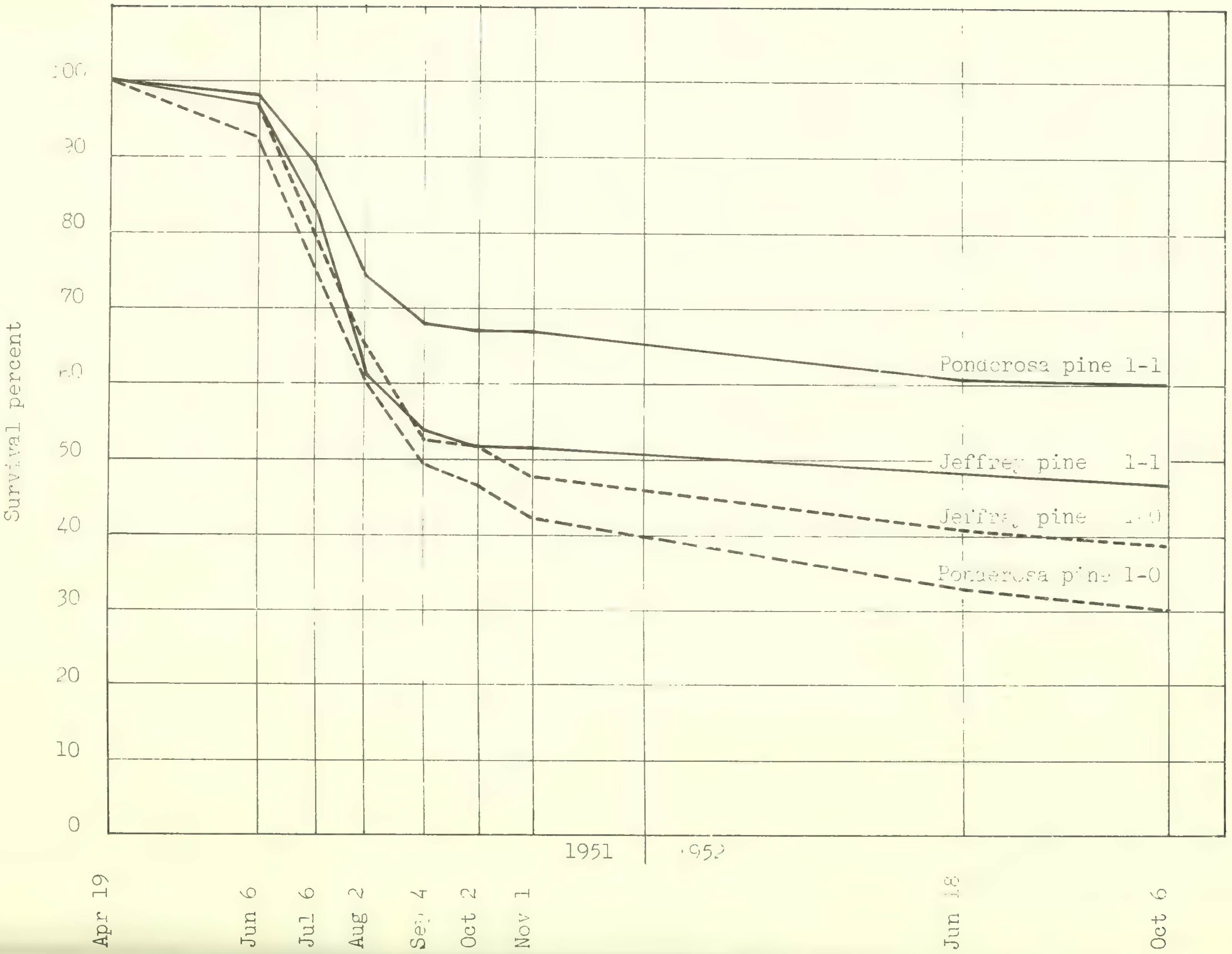
* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.


Survival percent
100
90
80
70
60
50
40
30
20
10
0
Ponderosa pine 1-1
Jeffrey pine 1-1
Jeffrey pine 1-0
Ponderosa pine 1-0
1951
1952
Apr 19
Jun 6
Jul 6
Aug 2
Sep 4
Oct 2
Nov 1
Jun 18
Oct 6

Ponderosa pine 1-1 stock had the best first- and second-year survival, and Jeffrey pine 1-1 stock was second best. According to variance analyses the difference in survival between age classes of stock was significant for the first year and highly significant the second year. Differences between species were not significant. The better average survival of transplants is consistent with general experience in California so the results do not alter recommendations for choice of planting stock.

Effects of Ground Conditions Upon Survival

Observations concerning the effect of particular habitat where each tree was planted add more to our understanding of factors affecting success in planting than does the performance of types of planting stock.

To secure habitat data the ground conditions and the density of cover were classified after planting for each 4 x 4 foot area surrounding the tree. The surface conditions were (a) bare mineral soil, (b) slash, (c) stones, (d) squaw carpet (Ceanothus prostratus Benth.) (e) other shrubs (including common sagebrush, Artemisia tridentata Nutt.), and (f) grass or sedge (Carex rossii Booth.). A planted spot was classified as having a light cover if only 1 to 25 percent of the area was covered; medium if 26 to 50 percent; heavy if 51 to 75 percent; and very heavy if 76 to 100 percent was covered.

On the average, the trees survived best on bare soil which had no stones; second best under slash; third on open stony ground; fourth in shrub cover; fifth in grass and sedge; and last in sqaw carpet (table 1). The density of the stones or ground cover also affected survival. For example, planted spots with light slash had the best survival, but spots covered with heavy slash had relatively low survival.

The differences in survival appear to be associated chiefly with differences in soil moisture supply. Vegetation depletes the soil moisture, and stones lessen the moisture-holding capacity of the soil mass. Heavy slash makes it difficult for the planter to prevent surface debris from dropping into the planting hole. This debris is generally dry, and, therefore, reduces the moisture immediately available to the newly planted tree. Debris may also cause air pockets and excessive drying.

Slash also provides shelter for rodents, making convenient places for feeding on the young trees. Browsing rodents killed a significant number of planted stock.

Table 1.--Second-year survival of planted stock by ground conditions and density of cover

Ground condition	Survival when stones or ground cover was					
	0 (none)	1 - 25 (very light)	26 - 50 (light)	51 - 75 (heavy)	76 - 100 (very heavy)	All
			percent			
Bare	56 (239)[1]	--	--	--	--	56 (239)
Slash	--	63 (83)	55 (91)	48 (50)	31 (16)	55 (240)
Stones	--	47 (257)	44 (152)	38 (71)	21 (56)	42 (536)
Shrubs	--	45 (11)	38 (13)	17 (6)	0 (1)	35 (31)
Grass and sedge	--	35 (60)	9 (47)	0 (31)	0 (6)	17 (144)
Squaw carpet	--	0 (4)	0 (5)	0 (1)	--	0 (10)
All	56 (239)	51 (654)	41 (308)	33 (159)	22 (79)	44 (1,20

[1] Numbers in parentheses show the number of planting spots in each ground condition and density classification.

Statistical Analyses

Statistical analyses indicate that survival percentages depend upon ground conditions and the type of stock planted. For comparisons (Chi-square) of survival for different habitat conditions the data were grouped into five ground condition-density classes: (a) bare, (b) light non-living cover or stoniness (1-50 percent), (c) heavy non-living cover or stoniness (51-100 percent), (d) light living cover (1-50 percent), and (e) heavy living cover (51-100 percent).

After two years, differences between ground condition classes were either significant or highly significant for every type of planting stock with one exception--Jeffrey pine 1-0 stock (table 2). Differences in survival were highly significant between types of stock planted in spots without vegetation; but under light or heavy vegetative cover, where survival was universally poor, differences between planting stock were not significant.

Survival two years after planting by type of planting stock and ground condition groups

Ground condition	Survival by types of planting stock					Significance of differences between types of planting stock
	P.P.1-0	J.P.1-0	J.P.1-1	P.P.1-1	All	
	. . . . percent					
Bare	37 (46)[1]	50 (62)	62 (69)	71 (62)	56 (239)	Not significant
Light non-living cover or stoniness	36 (159)	41 (150)	55 (124)	68 (150)	50 (583)	Highly significant
Heavy non-living cover or stoniness	19 (47)	34 (44)	27 (56)	63 (46)	35 (193)	Highly significant
Light living cover	20 (35)	26 (35)	38 (42)	11 (28)	25 (140)	Not significant
Heavy living cover	0 (13)	0 (9)	0 (9)	7 (14)	2 (45)	Not significant
All	30 (300)	39 (300)	47 (300)	60 (300)	44 (1,200)	Highly significant
Significance of differences between ground condition classes[2]	S	N	HS	HS	HS	

[1] Figures in parentheses show numbers of planting spots in each ground surface condition group and planting stock classification.

[2] HS - highly significant
S - significant
N - not significant

CONCLUSIONS

Planting locations should be selected carefully. Stony and grassy areas should not be planted if more suitable places also need planting. If grassy, shrubby, or slash-covered sites must be planted they should be prepared by scarification, slash disposal, or other appropriate treatment.

Even in favorable planting areas, tree planters should be taught to select the best spots to plant, rather than be guided by mechanical spacing alone. Small patches of grass or other vegetation should be avoided, as well as very stony spots, or areas of heavy slash.

Agriculture--Berkeley

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR
U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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DEVELOPMENT OF HIGH-RISK TREES IN PONDEROSA AND JEFFREY PINE STANDS FOLLOWING SANITATION-SALVAGE CUTTING

By Malcolm M. Furniss, Entomologist
and William E. Hallin, Forester

Sanitation-salvage cuttings, which remove the trees most susceptible to attack by bark beetles (high-risk trees), have been very effective in reducing losses caused by the beetles in ponderosa and Jeffrey pine stands. In studies on the Blacks Mountain Experimental Forest, Bongberg [1] found that the cumulative reduction in insect-caused losses was more than 70 percent for a 10-year period following sanitation-salvage cutting. More recent data from the experimental forest indicate that losses are reduced for 15 or more years after the cutting.

Another question at least as important to the owner as the length of time that losses are reduced is how many new high-risk trees develop before the second cutting. The general situation in eastside pine is that the initial sanitation-salvage cuttings over a working circle or property are taking about 15 to 20 years. At the end of the first cutting cycle, when the second cutting begins, some other type of cutting, such as unit area control [2] probably will be employed. However, the quantity of new high-risk trees that have developed must be taken into account by the manager in calculating what other timber he should harvest while holding to a fixed allowable cut.

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[1] Bongberg, J. W. Results of 10 years of bark beetle control by logging high-risk trees, Blacks Mountain Experimental Forest, Lassen County, California. Forest Insect Laboratory, Berkeley, California (manuscript report). 18 pp. May 6, 1949.

[2] Hallin, W. E. Unit area control -- its development and application. Calif. Forest and Range Exp. Sta. Misc. Paper 16. 10 pp. October, 1954.

The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California.

The number of high-risk trees that develop during the 15 or 20 years after the first sanitation-salvage cut was determined by a study made in 1954. Four compartments on the Blacks Mountain Experimental Forest, where sanitation-salvage cutting had been conducted, were the site for this study. Two of the compartments had been cut in 1937 and two in 1938, leaving only the low-risk trees. These trees were reclassified as to risk in 1954; consequently, the results show the development of high-risk trees for periods of 16 and 17 years after sanitation-salvage cutting.

In 1954 high-risk trees averaged 1,110 board feet, or one high-risk tree per acre (table 1); at the time of cutting, high-risk trees averaged 3,000 board feet, or 2.7 trees per acre. In 1954 high-risk trees made up 7.7 percent of the estimated stand volume. In contrast, at the time of cutting in 1937 and 1938 high-risk trees made up 17.2 percent of the virgin stand volume. The volume of high-risk trees present 16 and 17 years after cutting was only 37 percent as great as in the virgin stand before cutting.

We can conclude that in stands similar to those at Blacks Mountain about 1,100 board feet per acre of high-risk trees may be expected at the second cutting 15 to 20 years after a sanitation-salvage cutting. This still represents a considerable reduction in high-risk trees in comparison with uncut stands.

Table 1.--Volume and number of high-risk trees [1] at the time of sanitation-salvage cutting and 16 and 17 years later

Compartment	Area	Original stand [2] volume per acre	High-risk trees at the time of cutting: Volume per acre	High-risk trees at the time of cutting: Number per acre	High-risk trees 16 & 17 yrs. after cutting: Volume per acre	High-risk trees 16 & 17 yrs. after cutting: Number per acre
	acres	bd. ft.	bd. ft.		bd. ft.	
G 2-14	81.3	17,480	2,740	2.4	770	1.1
G 8-10	63.4	19,210	2,680	1.9	1,180	1.0
B 25-1	112.7	16,310	2,590	2.5	1,500	1.3
B 27-4	95.7	17,460	3,890	3.8	880	.6
All	353.1	17,460	3,000	2.7	1,110	1.0

[1] Risk 3 and 4 ponderosa and Jeffrey pine.

[2] Pine only.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 88 May 15, 1953

K-SCREEN SEED SPOTS[1]

D. F. Roy and G. H. Schubert

A new type of protective screen for seed spots has attracted the attention of foresters on the Pacific coast. This screen[2] is cylindrical in form, 4 inches long, about 1 inch in diameter, and is formed from 8-mesh hardware cloth. Foresters have named this protective device a "K-screen".

K-screens appeal to the forester because they are relatively cheap, can be pre-loaded with seed and germinating medium before being transported to the field, can be placed quickly, and may not need to be removed from the seed spot. To protect the seed from rodents, the tops of the screens are pinched partially closed. It is anticipated that established seedlings will grow through the pinched tops without deformation, and that the screens will eventually decompose or be pushed open by the growing tree.

Field tested at the Blacks Mountain Experimental Forest and the Stanislaus Experimental Forest in 1950 and 1951, and at the Slate Creek Unit, Trinity National Forest in 1952, K-screens have not produced all the hoped-for results. If K-screens are partially closed at the top, they generally protect seed from rodents, but the screens have certain drawbacks.

Seedlings within K-screens are sometimes unable to emerge from the soil, particularly heavy textured soils, which, with the mechanical reinforcement of the screen, form a layer impenetrable to seedlings. Under certain field conditions K-screens are subject to frost heaving, and sometimes the cores of soil within the K-screens dry too quickly.

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[1] Summary of a detailed manuscript which can be obtained by writing to the Director, California Forest and Range Experiment Station, P. O. Box 245, Berkeley 1, California.

[2] Designed by Mr. Joseph Keyes, formerly Biologist, Control Methods Research Laboratory, U. S. Fish and Wildlife Service, now retired.

* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

When livestock or deer are abundant, K-screens are susceptible to damage by trampling. Larger rodents (probably ground squirrels, Citellus beecheyi fisheri Merriam) sometimes knock K-screens out of the soil. Nor is the microclimate found under K-screens as favorable as under cone- or dome-shaped screens. These results show that K-screens or the way they are used must be improved before they can be recommended.

Two modified K-screens are currently being tested under field conditions. The first modification is lengthening the cylinder two inches. The second change lengthens the cylinder one inch and attaches the screen to an 8-inch stake[3] which is driven into the ground. Added length, plus the stake in the second case, should anchor the screens in the ground more securely and may reduce losses from frost heaving and animal disturbance.

Finally, there is a possibility of finding a material for filling the screens which would provide better germinating conditions than soil. If such a material is found the major deficiencies of the K-screen would be removed.

3/ Designed and being tested by Norman E. Dircksen, timber management staff member, Stanislaus National Forest.

FOREST RESEARCH NOTES
U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE
EXPERIMENT STATION *
STEPHEN N. WYCKOFF, Director

No. 89 May 15, 1953

POSSIBLE MEANS OF REDUCING MOUNTAIN PINE BEETLE ATTACKS IN YOUNG SUGAR PINE

V. A. Clements[1]

The mountain pine beetle (Dendroctonus monticolae Hopk.) is well known as a periodic threat to mature Western white pine, lodgepole pine and sugar pine, and occasionally to young ponderosa pine. A recent outbreak on the Sierra National Forest provides the first recorded case of heavy killing of young sugar pine.[2]

The Sierra outbreak is in the Miami Creek, Lewis Creek, and Big Creek drainages just south of Yosemite National Park. It has been estimated that in 3 or 4 years before May 1952, at least 10,000 young sugar pine and ponderosa pine were killed in this area.

The implications of this epidemic are serious. Such outbreaks must be prevented or greatly reduced in intensity if sugar pine is to be maintained as a commercial timber tree. Direct control on the Sierra area has reduced epidemic losses by 60 to 70 percent,[3] but is only a temporary expedient. Too expensive to be used as a regular management practice, direct control removes infested trees but does not alleviate conditions that tend to favor epidemics. The purpose of this paper is to report briefly the results of a study aimed at learning something about stand conditions that lead to mountain pine beetle epidemics, and to suggest possible remedial measures.

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[1] This study was made possible by the help of G. R. Struble of the Berkeley Forest Insect Laboratory, U. S. Department of Agriculture, and members of the staff of the Sierra National Forest, particularly C. E. Risbrudt, K. C. McLees, and the members of the forest's sugar pine delineation crews who collected the plot data. Their help is gratefully acknowledged.

[2] Struble, George R. 1952. Current developments, valuable second-growth sugar pine stands threatened. Forest Insect Laboratory. Berkeley, California.

[3] Hall, R. C., and M. M. Furniss. 1952. Forest Insect Conditions Miami Creek, Lewis Creek, and Big Creek drainages, Sierra National Forest. Office Report. Forest Insect Laboratory, Berkeley, California.

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Agriculture--Berkeley

The Data

The basic data for this study were obtained from 70 sample plots, 53 from the Miami Creek basin and 17 in the Lewis Creek drainage. Records were made on two types of plots: (1) "Stand plots," 1 x 1 chain in size (0.1) acre, spaced 5 chains apart on lines through areas known to be in the infested zone; (2) "Kill plots," to sample stands that had been subject to heavy kill, thereby supplementing information from the systematic stand plots. The kill plots varied in size to enclose groups of dead trees, ranging from 1 x 1 chain to 2 x 2 chains (0.4 acre). Kill plots were placed wherever groups were observed while setting out stand plots. The two types often coincided.

Information collected on both types of plots was:

1. All live trees of any species 2 inches d.b.h. and over were tallied by 2-inch classes. Sugar pine and ponderosa pine were further recorded by crown classes.

2. Insect killed pines were tallied by species, 2-inch d.b.h. classes, and two crown-class groups--dominant and codominant, and intermediate and suppressed. This grouping of crown classes was used since it was not possible to determine the exact crown class of dead trees, particularly of those dead 2 or 3 years.

3. Since the plots were tallied in July 1952 after the first direct control operation, the dead pines were further subdivided into two classes: (a) trees killed by the 1951 infestation (which had been treated) and any successfully attacked by 1952 broods of beetles, and (b) trees killed before the 1951 infestation. This rough classification by period of kill is the only measure of development and changes during the epidemic.

The Forest

The stands in this area are some of the finest, high site quality young sugar pine forests in California. The species composition varies considerably, but a large part of the young stands are mixed-conifer types with substantial proportions of sugar and ponderosa pines. By numbers of trees, the original stand on the plots averaged 30 percent sugar pine, 7 percent ponderosa pine, 25 percent white fir, and 38 percent incense cedar (table 1). The total number of trees, 658 per acre, indicates a well stocked stand. If stocking is rated by stand density index[4], that is, the number of trees in relation to average d.b.h. of the stand, this stand has a stand density index of 390. Reineke indicates [4] that for small heavily stocked plots, a stand density index of 800 is about the maximum stocking for mixed-conifer stands. On that basis these Sierra National Forest stands would be about 50 percent stocked, which experience indicates is an excellent average stocking for a large area.

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[4] Reineke, L. R. 1933. Perfecting a stand-density index. Jour. Agric. Res. 46: 627-638.

Table 1.- Live, dead, and original number of pines and number of white fir and incense cedar, by d.b.h. groups. Average for 70 plots.

	Sugar Pine			Ponderosa Pine					All species	
.h. oup, in.	Orig. stand	Live	Dead	Orig. stand	Live	Dead	White Fir	Incense Cedar	Orig. stand	Remain. stand
	. . . . . . Number of trees per acre									
- 10	145.2	48.2	97.0	33.9	12.6	21.3	136.6	229.8	545.5	427.2
- 16	32.9	14.9	18.0	9.0	6.9	2.1	18.6	10.5	71.0	50.9
- 22	11.2	7.6	3.6	2.9	2.8	0.1	7.1	3.2	24.4	20.7
- 28	4.7	3.2	1.5	1.1	0.9	0.2	3.6	2.0	11.4	9.7
- 34	1.0	0.9	0.1	0.8	0.8	-	1.4	1.1	4.3	4.2
and over	0.1	0.1	-	0.1	0.1	-	-	1.6	1.8	1.8
Total	195.1	74.9	120.2	47.8	24.1	23.7	167.3	248.2	658.4	514.5

The stands in the study area developed from advance reproduction and natural regeneration after logging as much as 50 years ago. There is an overstory of mature and overmature trees left by the early loggers on much of the area. Age of the young pine in these stands ranges from 40 to 70 years.

What Happened to the Forest

In the few years since 1949, when the mountain pine beetle began to show unusual activity in the stands, losses in sugar pine and ponderosa pine on the sample areas have been very heavy. Sixty-two percent of the sugar pines in the original stand have been killed, and 50 percent of the ponderosa pines (table 1). The net effect of these losses has been to reduce the pine component of these plots from 36.7 percent of the number of trees of all species to 19.2 percent in 1952. Losses outside the plots probably have been substantially less than on the plots, because the "kill plots" were deliberately placed in severely damaged areas.

Most of the insect losses were in the small diameter classes. Trees less than 12 inches d.b.h. made up 80 to 90 percent of the losses in sugar pine and ponderosa pine respectively. However, many of the dead trees were from the upper crown classes. The total number of pines killed on the plots was 1130, of which 348 were in the dominant and codominant group and 782 intermediate and suppressed. These losses represent 44 percent and 69 percent of the original numbers present in these crown class-groups.

Losses in Relation to Stand Characteristics

The plot data were used to study the relation between stand attributes and losses. Such factors as number of trees, number of pines, percent of the stand composed of pine, and several others were considered. Most of them showed no relation to insect losses. The results of a series of statistical analyses show that the following factors were not significantly related to the occurrence of insect losses:

1. Total number of trees per acre of all species.
2. Total number of pines per acre.
3. The number of pines expressed as percentage of the total number of trees.

Two characteristics, stand density index and crown class, both showed significant correlation with occurrence of insect attack. The greatest losses occurred where the stand density index was high. Stand density index is a more sensitive indicator of stocking than number of trees because it evaluates density of stocking by number of trees in relation to the average diameter of the stand. The number of intermediate and suppressed pines is important since the plot data show that the greatest kill in the early stages of the epidemic is in the understory trees. When the data are divided at the 1951 infestation, 77 percent of the trees killed before the 1951 attacks were intermediate and suppressed, in contrast to 47 percent of the trees killed by the 1951 and later attacks. Apparently the mountain beetles attacked the weak understory trees first, and as the infestation gained in intensity the beetles were able to attack and kill a greater number of the more vigorous overstory trees.

Suggested Stand Treatments

The results of this study point to two stand conditions that seem to indicate susceptibility of young sugar pine stands to attack by the mountain pine beetle. These conditions are: (1) high density of stocking as reflected by stand density index, and (2) the presence of understory (intermediate and suppressed) pine trees that seem to be attacked first.

The practical implications are that the ability of stands to resist attack may be improved either by reducing stand density or by removing trees which are especially susceptible. Reducing the stand density would, of course, be an indirect method of improving the vigor of the remaining trees. It is based on the observation that if released from competitors, trees which are not too badly suppressed or stagnated often improve in growth rate and general vigor. A cutting designed to reduce stand density might take the form of a commercial harvest that would remove larger trees of sawtimber size. These would include the overmature and mature trees left by the early logging, and younger white fir and incense cedar of merchantable size.

From the analysis of the stand data it has been determined that a considerable volume of merchantable material can be cut. If 24 inches d.b.h. is the lower limit of cutting, at least 10,000 board feet per acre is available. Of this volume at least 4,000 board feet is pine. A cutting of this degree should still leave an average of 10,000 to 12,000 board feet per acre of young pine and 4,000 to 5,000 feet of fir and cedar. It should be noted that the loss in pine in the recent outbreak was about 4,000 board feet per acre or 25 percent of the total pine volume.

Removal of the more susceptible trees, the second alternative suggested by the study, would be a more direct method. It would require a cash outlay that could not be recovered because the smaller susceptible trees have little or no market value at present. In addition to eliminating the trees which are more likely to nourish an insect attack during the population build-up stage, this alternative method would also serve to reduce stand density somewhat.

Although we cannot be certain just how effective either of the suggested methods would be in lessening tne danger of mountain pine beetle attack, they both appear to offer considerable promise. Probably, the best recommendation which can be offered at present is a combination of both kinds of cutting. A commercial cutting should more than pay its way while resulting in a substantial reduction in stand density, and thus pay for all or part of the expense of eliminating many of the small, more susceptible trees.

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

DEPARTMENT OF FORESTRY
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

No. 90

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CULL AND BREAKAGE FACTORS FOR PINES AND INCENSE-CEDAR IN THE SIERRA NEVADA

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This Research Note is an interim report of a study to determine the cull and breakage factors for all the commercial conifers in the Sierra Nevada. When the study is completed, factors for all the species will be published in the series of Forest Survey Releases reporting cull and breakage factors for forest trees in California.

The amount of cull due to defect, such as decayed wood or shake in living trees is expressed as a percentage of the gross volume of a stand to give the cull factor for that stand. When the stand is harvested there will be additional loss due to breaking of sound wood in the process of felling and bucking. This additional loss, when expressed as a percentage of the gross volume of the stand, is the breakage factor for that stand.

The cull and breakage factors presented here are of the general or "flat factor" type. They were prepared for use in the Forest Survey and were derived from averages of cull for two subregions -- the eastside and westside Sierra Nevada; therefore, they should not be expected to apply to individual trees, nor to give accurate estimates for stands of limited area. Rather, these factors should be applied to extensive stands or tree groups which are units of such stands.

Cull factors become larger with increasing age of the trees. For this reason, separate cull factors have been determined for tree classes constituting different age groups in Dunning's tree classification. [1]

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[1] Dunning, Duncan. A tree classification for the selection forests of the Sierra Nevada. Jour. Agri. Res. 36(9):755-771. May 1, 1928.

Although more breaks occur in harvesting older trees, the percentage occurring in sound wood remains fairly constant. This is especially true in the more defective species such as incense-cedar. Because the percent of breakage for incense-cedar is so small in comparison to the cull factors, different breakage factors are not given for each of the tree classes or age groups in this species. Separate breakage factors are presented, however, for the various age groups in the less defective and more valuable pine species.

Use of Cull and Breakage Factors

To determine the net sound volume in standing trees, use only the cull factors, but to determine the net harvestable volume, use both the cull and the breakage factors.

To use these cull factors properly, the cruiser will need to tally trees by classes or age groups. The gross volume of all trees in each class or age group is then discounted by the percentage indicated as the cull factor for that group.

Breakage factors for the pines also are applied to age groups. For incense-cedar, the breakage factor is a constant for all age groups. Breakage factors are directly additive to cull factors for the determination of the total woods loss when a stand is harvested.

Some of the data upon which the breakage factors are based were collected in an earlier logging era; consequently the factors may be somewhat low when employed with the current felling methods and generally rougher logging shows.

Factors for the Commercial Pines

Cull and breakage factors for ponderosa, Jeffrey and sugar pine in the Sierra Nevada are given in table 1. Separate factors were originally computed for Jeffrey pine, but since the factors were not significantly different from those for eastside ponderosa, and since these species are not always readily separated, combination factors for Jeffrey pine and eastside ponderosa were considered more convenient. Likewise, separate factors for eastside sugar pine were originally computed, but later regarded as not significantly different from westside sugar pine factors. Over-all factors then were computed for this species throughout the Sierra Nevada. In a few localized areas on the eastside, where old sugar pines occurred on pumice soil, shake was found so prevalent that cull in class 5 trees was considerably greater than average for the species. Although most class 5 trees on such areas have already been cut, any cruiser who encounters old trees on pumice soil should make local observations to determine to what extent the average factors should be increased to allow for the excessive shake.

Table 1.- Percent cull and percent breakage in ponderosa, Jeffrey, and sugar pine in the Westside Sierra and Eastside Sierra Subregions of California -- by Dunning's tree classes.

Subregion and Species	Tree Classes	Percent of gross board-foot (Scribner Decimal C) merchantable volume	
		Cull	Breakage
Westside Sierra	1, 2, 6	0.3	1.1
Ponderosa pine	3 and 4	1.2	2.2
	5 and 5A	3.8	2.4
	7	9.1	1.4
Eastside Sierra	1, 2, 6	3.8	0.5
Ponderosa pine and	3 and 4	3.8	0.9
Jeffrey pine	5 and 5A	4.1	1.9
Westside Sierra and	1, 2, 6	1.2	0.3
Eastside Sierra	3 and 4	3.7	3.7
Sugar pine	5 and 5A	6.3	3.8
	7	6.7	0

The cull and breakage factors given in table 1 are derived from 8 separate studies in which 3,138 trees of all classes were observed. In addition a large but undetermined number of trees, mostly in classes 5 and 5A, were measured on 20 timber sale areas. No class 7 pines were encountered in the study bases in the Eastside Sierra Subregion.

Factors for Incense-cedar

Cull factors for incense-cedar are given in table 2. The great bulk of incense-cedar occurs in the westside type, but a considerable amount also occurs in an intermediate type where cull is similar to that on the westside. The cull factors presented here are for these two types. Only a relatively small amount of cedar occurs in the typical eastside forest. A cull study conducted in this type near Eagle Lake, Lassen National Forest, on an open, dry, east slope showed cull in incense-cedar to be approximately one-half that on the westside. It is, therefore, suggested that cruisers who encounter this species on extra-dry sites in the eastside subregion, apply cull factors equal to one-half those given in table 2. On other eastside sites, the entire factors are applicable.

Table 2.- Percent cull and percent breakage in incense-cedar in the Sierra Nevada[1] -- by Dunning's tree classes.

Tree Class	Percent of gross board-foot (Scribner Decimal C) merchantable volume	
	Cull	Breakage
1	6.2	2.2
6	6.3	2.2
2	8.3	2.2
3	20.9	2.2
7	28.1	2.2
4	30.3	2.2
5	67.7	2.2

[1] In open stands on dry east slopes in the typical Eastside Sierra Subregion, cull factors equal to one-half the values given should be used.

The basis for these cull factors was provided by studies made at 5 locations. Two were cull studies and 3 dissection studies involving 1,536 trees of all tree classes. The supplemental study made near Eagle Lake consisted of 100 incense-cedar trees.

Breakage in incense-cedar is inconsiderable in comparison to the large amount of cull and generally differs little by tree classes. Hence it was desirable to use but one average breakage factor for all tree classes. In timber sales and cull studies at 19 different localities distributed throughout the Sierra Nevada, the average breakage factor for this species was 2.2 percent (table 2).

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

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DETERMINING THE AGE OF BLISTER RUST INFECTION ON SUGAR PINE

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Early investigations of white pine blister rust in the Pacific Northwest provided a large basis of infection data, from which Lachmund 1/ devised a method to postdate infections on western white pine. He found that rust cankers originating in a single year were consistently distributed in a characteristic pattern on the pine trees -- most of the cankers were to be found on wood grown in the year before the time of infection. A recent test shows that his findings also apply to sugar pine in California and Oregon.

Lachmund designated the pine growth of the year of infection as "a," the adjoining interwhorl 2/ of the previous year's growth as "b," the third youngest interwhorl as "c," and so forth. When cankers were tallied by interwhorls, more than half the cankers originating in a given year were on the "b," interwhorl (table 1). The "a" growth could then be identified, and since this was the youngest interwhorl infected that year, the age of the "a" interwhorl was taken as the age of the infection wave tallied.

Lachmund's method of determining the age of rust infection has been used by blister rust workers in southern Oregon and northern California to determine the age of infection on sugar pines. General observations in southern Oregon indicated that the pattern of canker distribution was

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1/ Lachmund, H. G. Method of determining age of blister rust infection on western white pine. Jour. Agr. Research 46:675-693, illus. April 1933.

2/ In conifers, the lengths of stem between branch whorls have often been referred to in past literature as internodes, a usage botanically incorrect. The term "interwhorl" is not open to this objection.

similar on sugar pine to the pattern Lachmund determined for western white pine. Recently some workers in California have noticed a seemingly different pattern on sugar pine. For this reason there has been some doubt as to the accuracy of age determinations of infection on sugar pine based on Lachmund's pattern.

To determine the pattern of canker distribution on sugar pine, and the applicability of Lachmund's pattern in determining the year of infection on this pine species, analysis of canker distribution from infection of known age has been made from data on plots designed primarily to study the spread of blister rust. Records of infections occurring in a single season on four sugar pine plots in Oregon and two in California were used in this analysis.

The tallies for the four Oregon plots give patterns approximately the same as for western white pine (table 1). On the California plots the percentage of cankers originating on the "a" interwhorls of sugar pine was approximately twice that for western white pine. In either case, however, the general patterns for sugar pine were quite similar to that for western white pine, a major part of the cankers developing on "b" interwhorls. Any of the six tallies made from the sugar pine plots leaves no doubt as to the year of infection when Lachmund's method is applied. The correct age of infection was denoted by a tally of only 10 cankers on Black Rock Plot 3.

The relatively late date when pine infection occurred at Big Bar in California may account, at least in part, for the greater percentage of the cankers originating on "a" growth as compared to the Oregon plots. Rains providing moisture conditions suitable for pine infection normally occur later in the fall in the Sierra Nevada than at locations further north. By that time in the season the new needles developed on sugar pines during the year are physiologically nearly mature; they more nearly approach the condition of second year, or "b" needles than that of first-year needles at more northerly locations. Accordingly, the first-year needles at Sierran locations could be expected to be more receptive to the rust than those at the northerly end of the sugar pine range or in the commercial range of western white pine. The analysis of plot results reported here supports this inference.

Table 1. Distribution of blister rust cankers, originating in a single year, on the five youngest interwhorls, i.e., "a" year of origin, "b" previous year, "c" third youngest, et cetera.

Pine species and location	Percent of cankers originating on					No. of cankers used as basis
	a	b	c	d	e	
WESTERN WHITE PINE						
Lachmund's studies in the Pacific Northwest	9.8	53.2	31.3	5.2	0.5	5,879
SUGAR PINE						
California						
Plumas N.F.						
Big Bar Plot 1	19.1	40.4	31.9	8.5	0.0	47
Big Bar Plot 4	20.8	49.2	26.5	3.2	0.3	1,132
Oregon						
Deschutes N.F.						
Black Rock Plot 1	10.3	55.2	24.1	10.3	0.0	29
Black Rock Plot 2	4.8	45.2	35.7	9.5	4.8	42
Black Rock Plot 3	20.0	40.0	40.0	0.0	0.0	10
Black Rock Plot 4	5.9	41.2	23.5	29.4	0.0	17
All Oregon Plots	8.2	46.9	30.6	12.3	2.0	98
All Sugar Pine	19.8	48.7	27.0	4.1	0.4	1,277

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
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U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

DEPARTMENT OF
THE UNIVERSITY OF THE SOUTH
SEWANEE, TENN.

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EXPERIMENTS ON CONTROL OF ELYTRODERMA NEEDLE BLIGHT OF PINES BY SPRAYS

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Elytroderma deformans (Weir) Darker is a needle disease, with subsidiary effects on twigs of pines. The blight attacks ponderosa pine (*Pinus ponderosa* Laws.) over much of its range in the west and Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) in California. About 1945 the disease reached epidemic proportions on ponderosa pine in portions of Oregon and Idaho but it had subsided somewhat by 1954. Nevertheless it is still considered serious there and is a cause of concern in southwestern Montana. In California, the disease has been less severe than farther north but has been destructive in localized areas. Trees near Manzanita Lake in Lassen Volcanic National Park, and along the southwestern shore of Lake Tahoe, have been particularly damaged by the fungus. Tree growth has been slowed, some trees killed and the affected trees rendered very unattractive in appearance during much of the period of heaviest recreational use.

Mortality from the disease has necessitated salvage logging in severely affected stands on several national forests in Oregon and Idaho in order to prevent heavy losses. But salvage logging has resulted in no improvement in the condition of the residual stand. On several areas relogging has been necessary for two or three successive years to utilize additional trees dying from the disease or from bark beetle attacks induced by it.

In 1952 experiments were started on national-forest land near Lake Tahoe to test the possibilities of controlling the disease with fungicidal sprays. The tests were continued in 1953. It was felt that if satisfactory control by sprays could be demonstrated, the method would not only be useful in areas of particularly high value for recreational use, but might also be adapted for arresting epidemics in more extensive forest areas if practical methods of application by airplane could be worked out. This paper is to report these experiments and their negative results.

The California Forest and Range Experiment Station is maintained at Berkeley in cooperation with the University of California

The Fungus

Elytroderma deformans is an ascomycetous fungus belonging to the family Hypodermataceae. Like many other fungi, it has two spore forms. The time of appearance of these spore forms varies from year to year and from place to place. In general the imperfect, or pycnidial, stage is produced subepidermally on the killed portions of affected needles in May and early June. It is followed in the fall by the perfect, or ascus, stage -- the ascospores of which mature beginning about mid-September. The needles chiefly attacked are those produced the previous year on twigs that had previously borne infected foliage.

The time of year that infection takes place and the infecting spore form are not known. Since ascospores are released from the hysterothecium, or fruit body, only during moist mild weather, and the same conditions are also necessary for the germination of the spores, it was assumed that fall infection by ascospores was the normal condition. Additional evidence supporting fall infection is the fact that the needles reach full length and are mature in other respects before showing any signs of infection. Weir [1] at Priest Lake, Idaho, in 1914 performed controlled-infection experiments. He sprayed ascospores suspended in distilled water on twigs of healthy plants in the spring and then covered the twigs with paper bags. That fall the needles on the sprayed twigs turned reddish brown in spots. They became completely brown by next spring and produced mature ascospores of the fungus in May and June. It will be noted that these times of the year for discoloring of the affected foliage and for maturing of the ascospores occurred several months in advance of the normal time.

Materials and Methods

The fungicides used in this study were of two types: Those which cover the surface of the needles and act as protectants over a period of time and those which act as eradicants but give no lasting protection (table 1). Application was through a 300-gallon agitator-type commercial orchard sprayer developing 300 p.s.i. nozzle pressure, mounted on a 1½-ton flatbed truck. The plants treated were part of a young, uneven-aged stand in a cut-over area, the trees varying from seedlings of 2 feet to small poles of 50 feet in height. All were in areas heavily affected by Elytroderma deformans and had been diseased for several years before the start of the experiments.

1/ Weir, James R. Hypoderma deformans, an undescribed needle fungus of western yellow pine. Jour. Ag. Res. 6(8): 277-288. 1916.

Table 1.--Materials used in spray tests to control Elytroderma needle blight on ponderosa and Jeffrey pines

Trade Name[1]	Active Ingredients	Date Applied	Dilution in Water	Characteristics
Puratized agricultural spray	5% phenyl mercury triethanol ammonium lactate	9-29-52 8-31-53	3 qts. in 300 gal.	eradicant, penetrant
Zinc Coposil	4% copper 20% zinc	9-24-52 9-2-53	6 lbs. in 300 gal.	protectant, nonpenetrant
Orthocide 50 wettable	N-trichloromethyl thiotetrahydrophthalimide	9-23-52 9-1-53 10-5-53 10-6-53	8 lbs. in 300 gal.[2] 15 lbs. in 300 gal. 30 lbs. in 300 gal.	protectant, nonpenetrant
Opalate	Zinc dimethyl dithiocarbamate	9-26-52	6 lbs. in 300 gal.	protectant, nonpenetrant
Orthorix	Polymerized Sulphur	10-7-53	2 gal. in 300 gal.	eradicant, penetrant
Orthocide 50 wettable plus Orthorix	See above	10-8-53	10 lbs. Orthocide 2 gal. Orthorix in 300 gal.	See above
Sanilac	Summer oil	9-4-53	6 gal. in 300 gal.	protectant, nonpenetrant
Bordeaux	Copper Sulphate lime	9-25-52	12-12-300 (2-2-50) 24-24-300 (404-50)	protectant, nonpenetrant

[1] Sterox S-K as a sticker and spreader was added at the rate of 1 quart in 300 gallons of spray solution to the first 4 products used. The other products either have a similar material incorporated in them or need none. Trade names are used for simplicity; neither endorsement nor criticism of these or other products is intended.

[2] The area sprayed with 8 pounds of Orthocide 50 wettable on September 1, 1953, was sprayed a second time on October 5, using 15 pounds of the same material.

With one exception, a single application of 300 gallons of spray mixture of each material was made in late summer. This amount was enough to drench 200 to 300 trees, depending upon their size. In the one exception a second application at a higher concentration than the one first employed was made following additional recommendations received from the manufacturer. Only a single application was given in most trials because more than one application per season was considered economically impracticable for forest disease control.

No replications were made because the size of each sprayed area was rather large and the experiments were intended only as a preliminary screening procedure to indicate promising materials for further and more detailed tests.

As already indicated, the ascospores normally mature about mid-September and require moisture for germination. Moisture is also needed for the hysterothecia to open to release the ascospores. Rainfall records at Myers, California, a few miles distant, during September and early October (table 2) show sufficient rain fell before the 1952 spraying to permit infection if mature ascospores were present. For this reason the experiments were continued in 1953 when conditions were more favorable for preventative spraying.

Table 2.--Precipitation at Lake Valley Ranger Station Myers, California, for the period September 1 to October 15, 1952 and 1953

Date [1]	Precipitation Inches
1952	
September 10	0.15
September 11	0.14
September 12	0.50
September 19	0.04
September 20	0.01
September 27	0.02
1953	
September 26	0.15
October 10	0.02

[1] Measurable precipitation fell only on the indicated dates during the September 1 to October 15 period.

Results

None of the spray materials tried in 1952 and 1953 gave any indication of positive control. The first fall rains fell before spraying was started in 1952, but few mature ascospores were believed to be present during the rainy period of September 10 to 12. Nevertheless, negative results the following spring were provisionally attributed to infection during this period. In 1953 the experiments were repeated before the rains started, but the results were still negative. It must be concluded that under the conditions of application in these experiments, none of the materials tested will control *Elytroderma deformans*.

Discussion

The reasons for the complete failure of the materials tested to give any measure of control are obscure. Infection of needles initially protected could have occurred later in the fall, after the effectiveness of the fungicides applied had been dissipated by further rains. But a more reasonable explanation would seem to be that infection took place before the sprays were applied.

That infection occurred before spraying is indicated by another experiment. Twigs bearing diseased foliage were stripped of all visibly infected needles and then covered with sausage casing bags. The covers were placed on the twigs during the week August 10 to 14, 1953. In the spring of 1954 many dead needles were observed on the 1953 growth within these bags. The dead needles had a reddish cast characteristic of needles killed by *Elytroderma*. On June 2 and 3, 1954, inspection showed that 85 percent of the twigs had dead needles of the characteristic red color. Of these twigs, about 16 percent showed needles with pycnidia and nearly 4 percent had faintly visible hysterothecia. Ten percent of the branches were dead and 5 percent were uninfected. The bags were removed from the twigs at this time.

Additional observations made on September 22, 1954, showed that about 80 percent of the twigs still had dead foliage with the characteristic, though somewhat faded, color, and 37 percent of these had needles bearing well-developed hysterothecia. During the period from June to September the number of branches killed increased to 34 percent. Rodents cut an additional 10 percent of the bagged twigs during this period, and a number of the branches apparently recovered so that at this time about 10 percent of the bagged branches appear uninfected. The bags were applied in such a way that subsequent contamination from the outside is considered nil. Thus, infection must have occurred before August 10, 1953, or must have taken place subsequently from spores or other sources of infection present in or on the parts bagged at that time.

From spore-trapping experiments it has been determined that ascospores are present in limited quantities during the spring, as well as in the larger numbers found in the fall. Practically all of the limited number of ascospores that are discharged in the spring months appear before the middle of May[2], considerably before shoot growth starts on ponderosa and Jeffrey pines in the Lake Tahoe area. Any infection of the needles at this time would almost necessarily be accomplished within the buds from which the new shoots develop. The character and distribution of the new infection makes a spring ascospore source seem questionable. The pycnidiospores of the fungus develop in late May and early June, and would appear to be a more likely source of infection than the ascospores. However, definite information on the time and origin of infection under normal conditions must await the results of additional investigation, now under way, into the biology of the fungus. Until this information becomes available, further experiments on control by sprays appear inadvisable.

Summary

Commercial fungicides tested in 1952 and 1953 failed to control Elytroderma needle blight. The reason for this lack of control is not clear at the present time but could be due to: (1) reinfection by ascospores in the fall after the spray materials have been washed off or diluted by rain, or (2) infection in the spring or early summer before the sprays were applied by either ascospores or pycnidiospores.

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[2] Lightle, Paul C. The pathology of Elytroderma deformans on ponderosa pine. Phytopathology 44(10): 557-569. 1954

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

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DEVELOPMENT OF HIGH-RISK TREES IN PONDEROSA AND JEFFREY PINE STANDS FOLLOWING SANITATION-SALVAGE CUTTING

By Malcolm M. Furniss, Entomologist
and William E. Hallin, Forester

Sanitation-salvage cuttings, which remove the trees most susceptible to attack by bark beetles (high-risk trees), have been very effective in reducing losses caused by the beetles in ponderosa and Jeffrey pine stands. In studies on the Blacks Mountain Experimental Forest, Bongberg [1] found that the cumulative reduction in insect-caused losses was more than 70 percent for a 10-year period following sanitation-salvage cutting. More recent data from the experimental forest indicate that losses are reduced for 15 or more years after the cutting.

Another question at least as important to the owner as the length of time that losses are reduced is how many new high-risk trees develop before the second cutting. The general situation in eastside pine is that the initial sanitation-salvage cuttings over a working circle or property are taking about 15 to 20 years. At the end of the first cutting cycle, when the second cutting begins, some other type of cutting, such as unit area control [2] probably will be employed. However, the quantity of new high-risk trees that have developed must be taken into account by the manager in calculating what other timber he should harvest while holding to a fixed allowable cut.

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[1] Bongberg, J. W. Results of 10 years of bark beetle control by logging high-risk trees, Blacks Mountain Experimental Forest, Lassen County, California. Forest Insect Laboratory, Berkeley, California (manuscript report). 18 pp. May 6, 1949.

[2] Hallin, W. E. Unit area control -- its development and application. Calif. Forest and Range Exp. Sta. Misc. Paper 16. 10 pp. October, 1954.

ERKELEY

The number of high-risk trees that develop during the 15 or 20 years after the first sanitation-salvage cut was determined by a study made in 1954. Four compartments on the Blacks Mountain Experimental Forest, where sanitation-salvage cutting had been conducted, were the site for this study. Two of the compartments had been cut in 1937 and two in 1938, leaving only the low-risk trees. These trees were reclassified as to risk in 1954; consequently, the results show the development of high-risk trees for periods of 16 and 17 years after sanitation-salvage cutting.

In 1954 high-risk trees averaged 1,110 board feet, or one high-risk tree per acre (table 1); at the time of cutting, high-risk trees averaged 3,000 board feet, or 2.7 trees per acre. In 1954 high-risk trees made up 7.7 percent of the estimated stand volume. In contrast, at the time of cutting in 1937 and 1938 high-risk trees made up 17.2 percent of the virgin stand volume. The volume of high-risk trees present 16 and 17 years after cutting was only 37 percent as great as in the virgin stand before cutting.

We can conclude that in stands similar to those at Blacks Mountain about 1,100 board feet per acre of high-risk trees may be expected at the second cutting 15 to 20 years after a sanitation-salvage cutting. This still represents a considerable reduction in high-risk trees in comparison with uncut stands.

Table 1.--Volume and number of high-risk trees [1] at the time of sanitation-salvage cutting and 16 and 17 years later

Compartment	Area	Original stand [2] volume per acre	High-risk trees at the time of cutting: Volume per acre	High-risk trees at the time of cutting: Number per acre	High-risk trees 16 & 17 yrs. after cutting: Volume per acre	High-risk trees 16 & 17 yrs. after cutting: Number per acre
	acres	bd. ft.	bd. ft.		bd. ft.	
G 2-14	81.3	17,480	2,740	2.4	770	1.1
G 8-10	63.4	19,210	2,680	1.9	1,180	1.0
B 25-1	112.7	16,310	2,590	2.5	1,500	1.3
B 27-4	95.7	17,460	3,890	3.8	880	.6
All	353.1	17,460	3,000	2.7	1,110	1.0

[1] Risk 3 and 4 ponderosa and Jeffrey pine.

[2] Pine only.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

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HARDWOOD SPROUT MEASUREMENTS IN NORTHWESTERN CALIFORNIA

D. F. Roy, Forester
Division of Forest Management Research

Some California hardwood trees regenerate quickly after their aerial parts are destroyed by fire or logging. Quick recovery by sprouting may be desirable to prevent soil erosion or for other reasons. More often, however, hardwood sprouts are pernicious. They capture ground area which otherwise could be used to grow conifers; they compete with conifers and may suppress them; and their leaves often smother young conifer seedlings and transplants. If new sprouts develop vigorously, special treatments may be necessary to obtain adequate stocking of desired conifers, whether by artificial or natural means.

Some foresters have been concerned about areas of forest land in northwestern California which are producing only presently non-commercial hardwoods. Here hardwoods often dominate the vegetational cover after logging or fire, but their aggressiveness has not been studied. Foresters, therefore, may be interested in data about some of the more important sprouting hardwoods which prove that northwestern California, like some other parts of the United States, has a hardwood problem.

The Study

Sprouts were measured at two places--the Three Creeks Burn, which lies about 5 miles west of Willow Creek, Humboldt County; and the Slate Creek cut-over unit, which is 7 miles north and slightly east of Weaverville, Trinity County. Madrone (*Arbutus menziesii* Pursh), Oregon white oak (*Quercus garryana* Dougl.), locally called Brewer oak[1], tanoak (*Lithocarpus densiflorus* (Hook. and Arn.) Rehd.), and bigleaf maple

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[1] McMinn, Howard E. An illustrated manual of California shrubs. Berkeley and Los Angeles, California. 663 pp. 1951.

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(Acer macrophyllum Pursh) sprouts were measured at Three Creeks. Dogwood (Cornus nuttalii Audubon) sprouts were examined at Slate Creek.

The Three Creeks Fire began on August 18, 1951, and was not controlled until August 23. Starting in heavy logging slash, it burned intensely, clearing the ground of flammable material and killing almost all conifers and hardwoods alike. Consequently, the aerial parts of the parent trees producing the sprout clumps were dead.

The Slate Creek Unit was clearcut by alternate blocks in 1950 and 1951. Logging completely destroyed the parent dogwood trees. A large proportion of the clumps sprouted from former skid roads.

Sprouts were measured first on November 10, 1952, when data for madrone clumps were recorded. The madrone clumps, plus 50 Oregon white oak, 50 tanoak, and 10 bigleaf maple sprout clumps, were also measured on October 30, 1953, and September 16, 1954. The dogwood sprouts were measured on November 8, 1953, and October 13, 1954.

Sprout Development by Species

Sprout development was vigorous although differing between species. Growth of bigleaf maple sprouts has been most spectacular. They are the tallest [2]. They also have more sprouts and cover more ground space per clump than other species. At the end of the third growing season the average clump of bigleaf maple sprouts was 13 feet tall, 15 feet in diameter, and included 37 sprouts (table 1). Sprouting of bigleaf maple is not as important to foresters, however, as that of other species because the maple is not widely distributed. It grows only on stream banks or other situations where soil moisture is abundant.

Madrone sprouts were the second most vigorous. At the end of the third year these clumps averaged 10 feet in height, 8 feet in diameter, and 13 in number of sprouts. Although not as vigorous as bigleaf maple, madrone sprouts are more important in forestry because they are distributed more widely than other species except tanoak.

In order of decreasing vigor, madrone sprouts were followed by Oregon white oak, tanoak, and dogwood. But even the development of dogwood sprouts was impressive. In 3 years the average clump had 14

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[2] Comparisons in this report are made in the statistically significant sense.

Table 1.--Hardwood sprout development after burning or logging, northwestern California, 1952-54

Time since burning or logging, and species	Sprout clumps measured	Height of tallest sprout in clump		Crown diameter of sprout clump		Sprouts per clump	
		Average	Range	Average	Range	Average	Range
	No.	Ft.	Ft.	Ft.	Ft.	No.	No.
First year							
Madrone	50	4.7	1.6- 7.6	4.5	0.8- 8.9	17	1- 47
Second year							
Bigleaf maple	10	9.8	6.8-13.1	11.5	6.8-15.5	78	14-143
Madrone	50	7.7	3.2-11.5	6.8	2.0-13.7	16	1- 47
Oregon white oak	50	6.6	4.4-11.2	6.8	2.9-12.3	18	1- 57
Tanoak	50	5.2	2.2- 8.3	6.2	2.9-11.5	27	7- 79
Dogwood	50	4.2	1.2- 7.4	4.5	0.8- 9.1	19	1- 98
Third year							
Bigleaf maple	10	12.8	7.5-17.1	14.7	10.4-21.5	37	8- 67
Madrone	[1] 48	10.1	4.9-14.8	7.6	2.8-16.5	13	1- 32
Oregon white oak	[1] 49	9.2	6.1-12.8	8.2	3.5-12.3	10	1- 25
Tanoak	50	6.8	2.2-10.3	7.0	3.4-12.1	12	4- 25
Dogwood	50	5.9	2.4- 9.9	5.4	1.3- 9.4	14	1- 84

1/ Number of sprout clumps measured reduced by salvage logging operation.

sprouts, the tallest being 6 feet high, and was 5 feet in diameter. Comparison of dogwood sprouts with the others studied is not strictly valid because the dogwood clumps are growing about 50 miles further east in a different environment.

One ecological pressure affecting dogwood sprouts, but not others, was browsing by deer. On the Slate Creek Unit browsing damage to conifers has been almost non-existent, but 62 percent of the dogwood sprout clumps have been browsed to some degree. Of these, 10 percent were browsed heavily.

The number of living sprouts was reduced drastically between the second and third growing seasons. Weak sprouts died and growth was concentrated on fewer stems. Reductions were: bigleaf maple--from 78 sprouts per clump in the second year to 37 sprouts in the third year; madrone--16 to 13; Oregon white oak--27 to 10; tanoak--27 to 12; and dogwood 19 to 14.

When species were ranked by heights of the tallest sprouts, or by clump diameters, differences between species were statistically significant. For number of sprouts per clump, bigleaf maple had significantly more than other species, but the only other significant difference was between madrone (ranked second) and Oregon white oak (ranked fifth and last).

Diameter of Parent Tree Affects Sprout Development

Root systems increase in size as trees grow larger. Therefore, the root systems of larger parent trees should produce more vigorous sprout clumps. This hypothesis was checked by separate regression analyses relating diameter of the parent tree to height of the tallest sprout, to diameter of the sprout clumps, and to number of sprouts per clump. Measurements taken at the end of the third growing season were used.

Analyses showed that the diameter of the parent tree significantly affected the height and diameter growth of sprout clumps, and the number of sprouts per clump (figures 1, 2, and 3). For example, the tallest madrone sprout in a clump was 0.59 foot taller for each additional inch of the parent tree's diameter. Clump diameter increased 0.75 foot, and number of sprouts increased 1.77 for each additional inch of diameter. All regression coefficients were statistically significant except for bigleaf maple where sprout height and clump diameter were less dependent upon the parent tree's diameter.

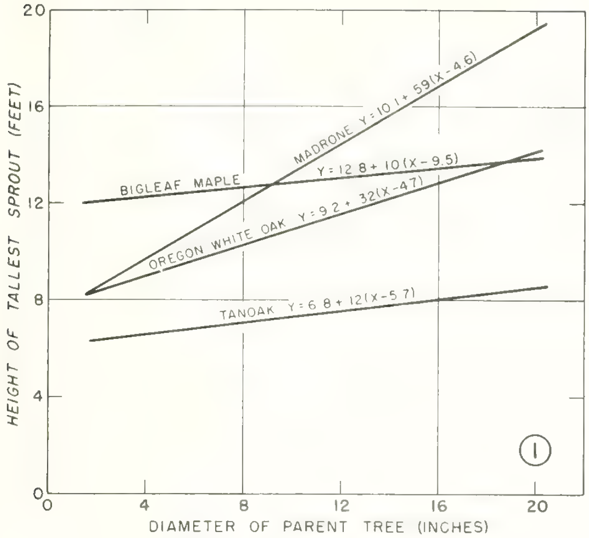

Figure 1.--Relation of height of tallest sprout in clump to diameter of parent tree, end of the third growing season.

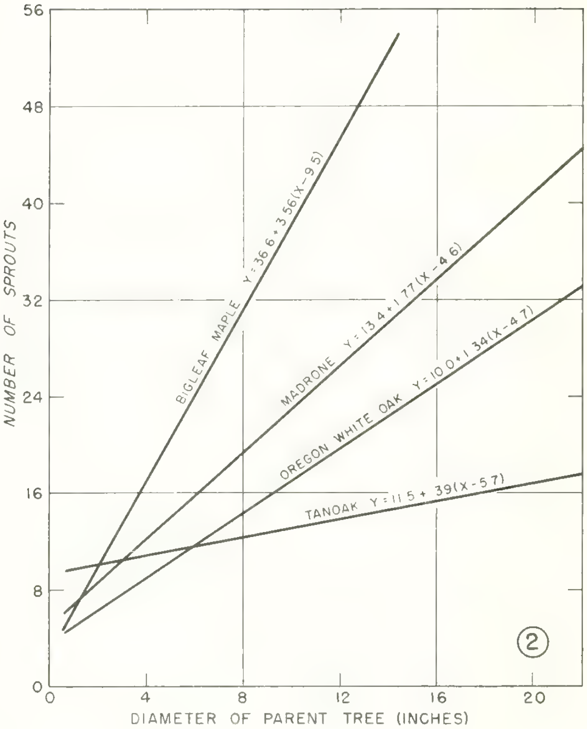

Figure 2.--Relation of number of sprouts per clump to diameter of parent tree, end of the third growing season.

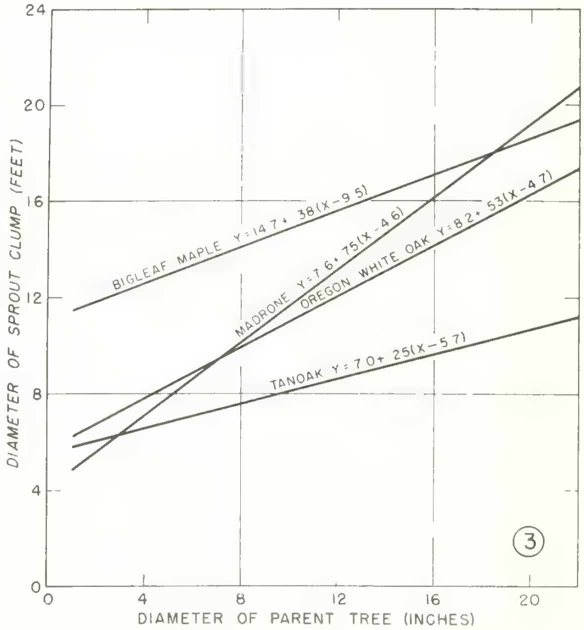

Figure 3.--Relation of diameter of the sprout clump to diameter of parent tree, end of the third growing season.

Conclusions

Conclusions from measurements of sprouts of hardwood trees in northwestern California are:

1. After destruction of their aerial portions by fire or logging operations, several kinds of hardwoods produced vigorous sprouts.

2. Sprout height growth differed by species; in descending order, bigleaf maple, madrone, Oregon white oak, tanoak, and dogwood.

3. The parent trees of larger diameter produced more sprouts, taller sprouts, and wider clumps.

These facts can be useful to the forester desiring to regenerate a burned or logged area. After spacing and species of potential sprout producers are determined in the field, information such as that presented here can be applied to calculate the ground area which will remain available for conifer reproduction. If hardwoods are too numerous, hardwood poisoning will be necessary and appropriate action can be planned well in advance. When trees or seed are planted, spots near living hardwood stumps or root crowns should be avoided. Small trees cannot compete with vigorous sprouts. Therefore, planting must be limited to places which will remain open until conifers dominate other vegetation.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 96 August 15, 1955

FREEZING INJURY TO SUGAR PINE CONES

Gilbert H. Schubert, Forester
Division of Forest Management Research

Evidence that immature sugar pine cones are killed by severe late spring freezes was observed for the first time on the Stanislaus Experimental Forest in 1954. Although extremely low temperatures previously were suspected to have destroyed young sugar pine cones, no definite instances are known to have been reported heretofore.

In August 1954, at the time of the annual cone count in the experimental area, many small cones were observed on the sugar pine trees. At first glance, these appeared to be green conelets that would mature in 1955. Upon closer examination, they proved to be brown and slightly larger than green first-year conelets on the same trees. On the ground beneath the trees, several of these brown cones were found. None had the resin globule on the stem characteristic of cones killed by larvae of the sugar pine cone beetle (Conophthorus lambertianae Hopk.). Furthermore, these brown cones were much smaller than insect-killed cones and showed no visible cause of death (fig. 1).

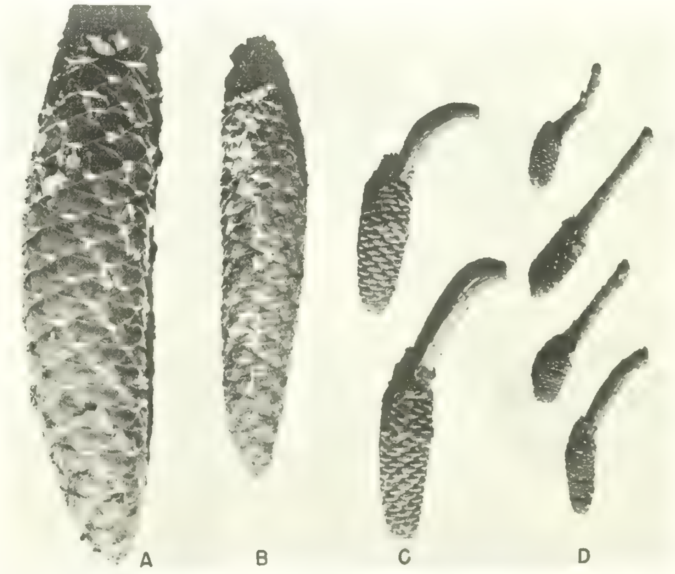

Figure 1.
Sugar pine cones:

A. Normal appearance in August of second year.

B. & C. Killed by sugar pine cone beetles.

D. Killed by a severe June freeze.

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RKELEY

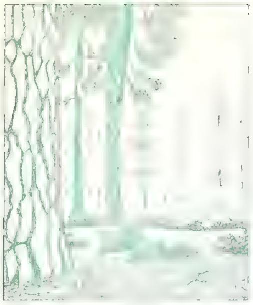
Records from the nearest weather station were examined for clues to the cause of damage. The recording station is about 2.5 miles northwest of the study area and about 1,000 feet lower in elevation. The weather station and the study plot were in different drainages, but both were on south-facing slopes. A minimum temperature of 20° F., an unusually low temperature, was recorded for June 6 in the weather instrument shelter 4.5 feet above the ground level. This freeze, which occurred after trees around the shelter had started to grow, killed most of the new shoot growth, particularly on the white firs. The maximum and minimum temperatures during the 30-day period immediately preceding the freeze were:

	Maximum (°F.)	Minimum (°F.)
Average	70	35
Range	47-84	27-45

Although the exact minimum temperature in the crowns of the study trees is not known, it probably was as low or lower than at the recording station.

Not all of the immature sugar pine cones were affected by the freeze. Approximately 8,400 cones were counted on 95 trees. Of these cones, 1,485 were classified as frozen. The frozen cones occurred on 35 percent of the trees, generally isolated individuals. Losses appeared to be higher in the upper halves of the crowns, but no cone counts were made to verify this observation. A substantial part of the frozen cones--46 percent--were found on a single, isolated, 49-inch tree. This tree was situated about midway on a southeast slope. More than 93 percent of the cones on this particular tree appeared to have been frozen.

Although sugar pine cone crops have been observed for the past 29 years on the experimental forest, the occurrence of frozen cones has never been reported. Probably some frozen cones have been erroneously classified in the past as "next year's cones." Therefore, losses resulting from late spring freezes may explain why some cone crops were lighter than predicted or failed completely.



FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 97

August 25, 1955

CALIFORNIA CONE CROP--1955

Gilbert H. Schubert, forester,
Division of Forest Management Research

California forest trees produced a good cone crop in only a few localities in 1955. Generally the crop was fair or less, with no crops or poor crops about as frequent as fair ones. These are the main conclusions from a study of cone-crop reports furnished the California Forest and Range Experiment Station by members of the California Division of Forestry and of the administrative branch of the U. S. Forest Service. The reports were based on occular estimates in which the crop was rated as none, very poor, poor, fair, and good. Although subjective, the ratings provide valuable information for those planning to collect seed.

As an aid to seed collectors, the crop reports have been segregated according to the forest tree seed collection zones described by Fowells. [1] This grouping (table 1), showed that the most promising localities for collecting seed of important species were as follows:

Redwood	Zone XIII
Giant sequoia ...	Zones IV and V
Sugar pine	Zone IV
Douglas-fir	Zone XI
Red fir	Zone II (lower part) and Zone IV (upper)
White fir	Zone IV
Coulter pine	San Benito County

A map of the collection zones is appended to this note, but since the seed crop varies widely in some zones, it is also advisable to consult field officers of the California Division of Forestry or the U. S. Forest Service.

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[1] Fowells, H. A. Forest tree seed collection zones in California. U. S. Forest Service. Calif. Forest and Range Expt. Sta. Res. Note 51, 5 pp., illus. 1946.

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Table 1.--Summary of cone crops by species and seed zone, California, 1955

Species	County or Seed Collection Zone	Cone Crop 1/
DOUGLAS-FIR:		
Bigcone Douglas-fir (*Pseudotsuga macrocarpa*)	IX	Poor
Douglas-fir (*P. menziesii*)	II	Poor to fair
	IV, V	None
	XI	None to good
	XII, XIII	Fair
FIR:		
Lowland white fir (*Abies grandis*)	XIII	Fair
Red fir (*A. magnifica*)	III	Poor to fair
	II, IV	None to good
	V	None
	X	Fair
Silver fir (*A. amabilis*)	X	Poor
White fir (*A. concolor*)	II, III	Poor
	IV	None to good
	V	None
	X	Fair
PINE:		
Bishop pine (Pinus muricata)	XIII	Fair
Coulter pine (*P. coulteri*)	Contra Costa	Poor to fair
	San Benito	Good
Jeffrey pine (*P. jeffreyi*)	I	Fair
	II, III, IV, V, VI, VIII, IX, X	None to poor
Lodgepole pine (*P. contorta*)	XIII	Fair
Monterey pine (*P. radiata*)	XIII	Fair
Ponderosa pine (*P. ponderosa*)	I	None to fair
	II, IV	None to poor
	V, VI, VIII, X	None
Sugar pine (*P. lambertiana*)	II, III	Very poor to poor
	IV	None to good
	V, X	Poor
SEQUOIA:		
Giant sequoia (*Sequoia gigantea*)	IV, V	Fair to good
Redwood (*S. sempervirens*)	XII	Fair
	XIII	Good

1/ Reported by technicians of the California Division of Forestry and the California Region, U. S. Forest Service.

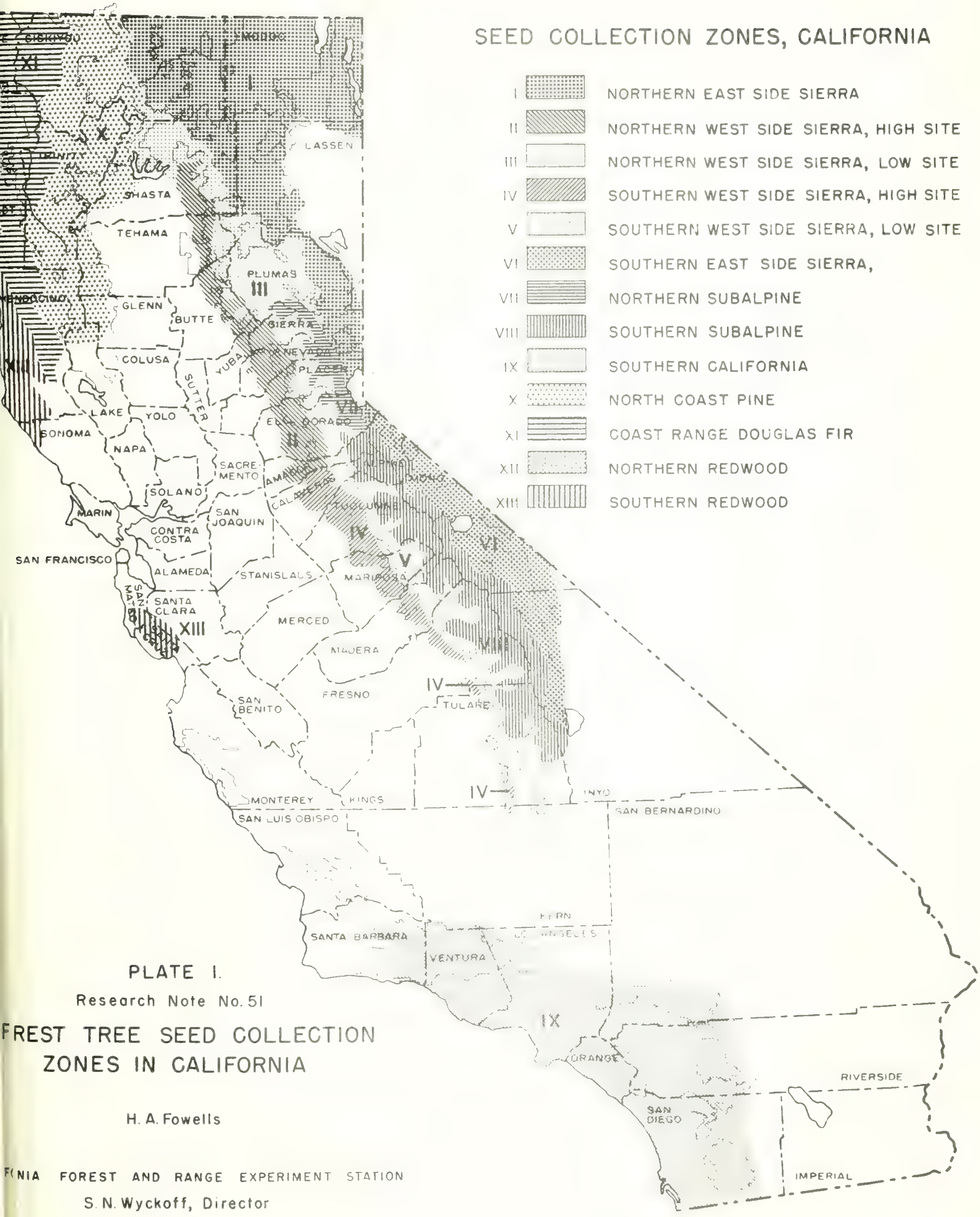

PLATE I.

Research Note No. 51

FREST TREE SEED COLLECTION ZONES IN CALIFORNIA

H. A. Fowells

NIA FOREST AND RANGE EXPERIMENT STATION
S. N. Wyckoff, Director

SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 99

October 20, 1955

AIR DELIVERY OF WATER HELPS CONTROL BRUSH AND GRASS FIRES

By Joseph B. Ely, Fire Control Officer, Mendocino National Forest, and Arthur W. Jensen, Forester, Division of Forest Fire Research, California Forest and Range Experiment Station.

Dropping water or fire-retardant chemicals from low-flying aircraft can help ground forces control brush and grass fires. That such water drops are practicable has been demonstrated by a recent series of field trials and calibration tests conducted by the Mendocino National Forest and the California Forest and Range Experiment Station in cooperation with the Willows Flying Service, the California Division of Forestry, and the Arcadia Equipment Development Center. As much as 120 gallons of water at a time was carried to fires in an airplane normally used for crop dusting and other agricultural purposes. Water dropped through a single outlet designed by the Willows Flying Service proved effective in quieting hot spots on large fires and in retarding spread of small fires in brush and grass.

Previous studies [1] have established several guidelines for dropping water from aircraft:

1. The danger to men, equipment, and buildings prohibit the use of missiles or droppable containers--in fact, any projectile--in populated areas or as close support to fire fighters on the ground.

2. Aircraft must be maneuverable and have a considerable reserve of power.

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[1] See Bibliography, page 12.

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3. Pilots should be capable of flying close to rough topography and of achieving pinpoint accuracy with safety.

4. Water dropped free-fall reaches the ground and has a significant effect on some fires.

In consideration of these guidelines, it was decided to test the adaptability of an agricultural aircraft as an aerial tanker, and to attempt drops of uncontained water on fires.

THE AERIAL TANKER

At the suggestion of the fire-control staff of the Mendocino National Forest, the Willows Flying Service adapted a plane used in agricultural work for trial as an aerial tanker. This plane, a 450-horsepower biplane (fig. 1), has a 160-gallon tank in the fuselage and is equipped with conventional valves and nozzles for agricultural spraying and seeding operations. The spray equipment was removed and a single outlet was installed at the base of the tank (fig. 2). Removing the conventional equipment and installing the special tank outlet requires about 4 hours.

The outlet measures 7 by 18 inches and is constructed of heavy sheet metal. The outlet gate is hinged at the front and has a rubber gasket to insure watertight seal. At first, the gate was equipped with a simple latch released from the cockpit. With this arrangement, the sudden release of water caused the plane to jump about 100 feet and the pilot to black out temporarily. This difficulty was corrected by equipping the outlet gate with a controlling lever which permitted the pilot to open the gate more slowly, and in all subsequent tests when full loads were dropped the gate was opened slowly at first.

PRELIMINARY TRIALS

Preliminary trials were conducted in early August 1955 over flat ground at an airport. These trials showed that water could be dropped successfully from this aircraft. In the first trial, a load of 120 gallons of water was dropped from an elevation of 30 feet at an airspeed of 80 miles per hour. The water from this drop covered an area approximately 30 feet wide and 285 feet long. A test fire in grass, 20 feet wide and 600 feet long, required three 120-gallon loads of water and 10 minutes of follow-up work by hand for control.

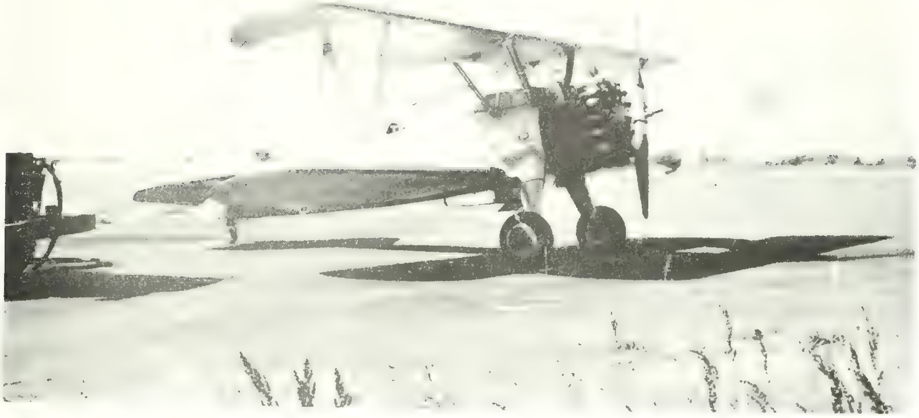

Figure 1. --The agricultural biplane used for the water-drop tests.

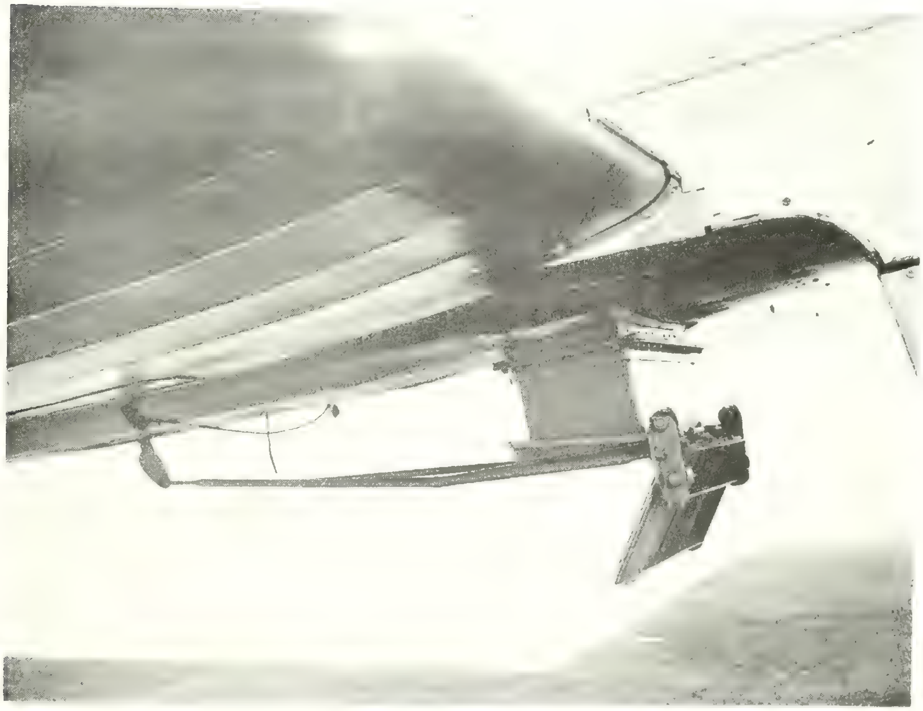

Figure 2. --Close-up of special tank outlet.

FIELD TRIALS

The next step was to try water drops on actual wildfires. During August the plane was used 4 times on 3 fires (table 1). In three trials the air tanker proved to be of considerable help to ground forces although in one of these it was apparent that too much was expected of a single plane. One fire was under control when the plane arrived so that the water drop was unnecessary though helpful in mop-up.

On initial attack the loaded plane was dispatched from its Willows base immediately after ground forces were started to the fire. At the same time, aviation gasoline and a water tanker were sent to the airport nearest the fire. Prominent, well known peaks were used as landmarks. A reconnaissance plane, in communication with ground forces and the "refill" airport, correlated the ground and air activity. In the future the company plans to fly a maintenance mechanic to the airport to refuel and load the air tanker, do maintenance work as necessary, and prevent damage to the plane by well intentioned but inexperienced personnel during the loading operations.

CALIBRATION TESTS

It was apparent that air delivery of water made this aircraft a practical fire fighting tool, but quantitative information was needed to improve tactical methods for water delivery. Accordingly, a limited series of tests was conducted at the Willows airport and Elk Creek Butte Lookout on August 31 and September 1, 1955 to obtain the following information:

1. The effect of plane height, plane speed, and wind velocity and direction on the amount and distribution of water received on the ground.

2. The amount of water loss to be expected during summer fire weather.

3. The effect on amount and distribution of dropping part of the total load in each of several runs (multiple passes) with the pilot aiming for the same spot each time.

4. The practicability of dropping a sodium-calcium borate fire-retardant from this aircraft.

Table 1. --Conditions and results of air tanker use on wildfires - Mendocino National Forest, 1955

Name of fire and date	Conditions	Plane use	Results
Mendenhall August 12	Fire about 400 acres; in grass, brush and timber. Crowning uphill. Weather hot, dry and windy.	Plane supported initial action forces on flank in grass and mixed oak with 240 gallons of water in 2 loads.	Effective support where used, but too much line for one plane to handle.
Mendenhall August 13	Weather similar to August 12. Fire 700 acres and temporarily controlled at head and one flank. Lower end of fire, burning downhill in chamise, too hot to handle by direct attack and threatening to outflank existing control lines.	Plane, re-filling repeatedly at nearby airport, delivered 600 gallons in 5 loads to 15 chains of lower end of fire.	Fire cooled down enough that attack forces were able to build control line along fire edge. Fire spread no further. Firefighters stated they could not employ direct attack until flames suppressed by plane. In this trial, 120 gallons applied in 6 passes[1] was not nearly as effective as when applied in 3 passes.
Mud Flat August 15	Fire about one-fourth acre and already controlled.	Plane load dropped anyway.	Water of some help to mop up. Need for better communications shown.
John David place August 15	Fire in bottom of narrow box canyon with adjacent slopes rising 2,000 feet on one side and 5,000 feet on the other. Burning in medium density mixed brush with grass. Head of fire controlled but hot-burning corner about to outflank control line. Corner too hot for direct attack and moving too fast for indirect attack.	Refilling at nearby airport, plane delivered 480 gallons in 4 loads to hot corner by flying up and down the canyon.	Hot corner cooled down enough to allow men to complete their control line close to fire edge. District Ranger and others reported air tanker instrumental in control.

1/ Plane made 6 runs, dropping part of load each time until 120 gallons dropped.

5. The amount of penetration of water and retardant into brush cover.

Procedure

For measuring the amount and distribution of water, 121 cans, 3 inches in diameter and 7/8 inches tall, were placed in a 50 by 300-foot rectangular grid. Within this grid the cans were spaced 5 feet apart across the width and 30 feet apart along the length. The cans were covered immediately after each test and the water received by each was weighed before making the next test. To measure penetration into brush, 10 pairs of cans were distributed in brush of different densities in the target area. Each pair consisted of one can at the top of brush crown, and one on the ground.

Wind direction and velocity were recorded automatically during each test. Temperature and relative humidity were measured immediately after each test. The line of flight of the plane with reference to the grid was also recorded.

Although this aircraft can carry a maximum of 160 gallons of water, nominal full-load tests were made with 125 gallons of water or 100 gallons of retardant. At elevations normally experienced on the Mendocino National Forest this is the maximum safe load.

Results

During the tests wind velocity varied from calm to 8 miles per hour, air temperature from 80 to 110°F, and relative humidity from 6 to 19 percent. In one test the plane's tail was low and the propeller wash blew over some of the grid measuring cans.

The patterns of distribution from these tests were roughly oval, from 4 to 7 times longer that wide (fig. 3). When the full load was released in one pass the greatest concentration of water was obtained when the airplane was flying at low speed and low elevation into the wind (tables 2 and 3). Both higher speed and greater elevation increased the total length of pattern but gave lower concentration.

About 75 percent of the water reached the ground in measurable quantities in the low-altitude, low-speed, headwind tests; about 65 percent in the higher altitude, crosswind tests. At top speed and low elevation, about 70 percent of the water released reached the ground. Only

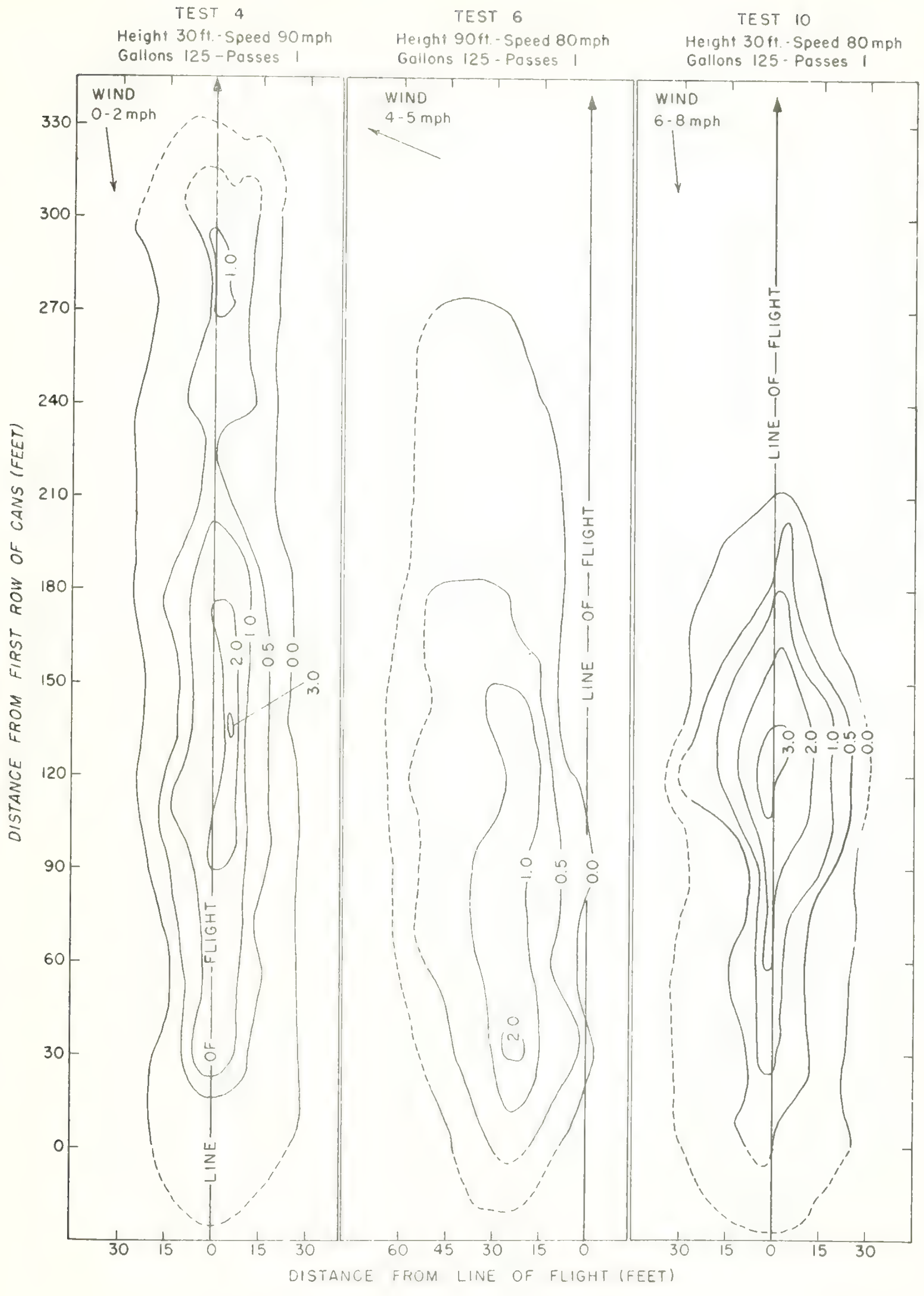

Figure 3. --Sample distribution patterns from water-drop tests; contour lines indicate concentration of water in gallons per 100 square feet.

Table 2. --Length of water pattern along line of flight, by concentration of water[1]

Test No.	Aircraft Height	Aircraft Speed	Wind Direction	Wind Velocity	Amount of Water dropped	No. of Passes	Total Length	Length when concentration (in gal. per 100 sq. ft.) was-- 0.5	1.0	2.0	3.0	4.0
	Feet	M.p.h.		M.p.h.	Gallons		Feet	Feet	Feet	Feet	Feet	Feet
2	30	80	Head	3-5	125	1	230	210	(2/)	(2/)	(2/)	(2/)
10	30	80	Head	6-8	125	1	240	212	160	100	30	15
4	30	90	Head	0-2	125	1	360	305	210	85	10	0
3	30	90	Cross	0-1	125	1	330	280	160	50	0	0
5	90	80	Cross	3-4	125	1	290	230	100	20	0	0
6	90	80	Cross	4-5	125	1	290	175	135	10	0	0
7	30	80	Cross	1-4	125	3	285	210	185	0	0	0
8	30	80	Cross	2-4	125	5	345	219	165	20	0	0
9	30	80	Head	0-1/2	40	1	210	175	113	30	0	0
11	30	80	Head	6-8	[3]40	1	165	(2/)	(2/)	(2/)	(2/)	(2/)

[1] Concentration measured along 5-foot strip parallel to fight line through area of greatest concentration.

[2] Collecting devices failed.

[3] Fire retardant chemical dropped.

Table 3. --Water distribution by area for different concentrations

Test No.	Aircraft Height	Aircraft Speed	Wind Direction	Wind Velocity	Amount of Water dropped	No. of Passes	Total Area	Area covered by concentration (in gal. per 100 sq. ft.) of-- 0.5	1.0	2.0	3.0	4.0
	Feet	M.p.h.		M.p.h.	Gallons		Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.
2	30	80	Head	3-5	125	1	9,613	(2/)	(2/)	(2/)	(2/)	(2/)
10	30	80	Head	6-8	125	1	11,332	5,644	4,000	1,656	269	26
4	30	90	Head	0-2	125	1	16,560	6,375	4,284	356	19	0
3	30	90	Cross	0-1	125	1	14,361	6,624	3,286	277	0	0
5	90	80	Cross	3-4	125	1	15,974	6,943	3,531	75	0	0
6	90	80	Cross	4-5	125	1	15,449	6,118	2,668	112	0	0
7	30	80	Cross	1-4	125	3	12,818	6,634	2,902	0	0	0
8	30	80	Cross	2-4	125	5	13,350	4,544	2,607	94	0	0
9	30	80	Head	0-1/2	40	1	7,275	3,038	1,569	150	0	0

[1] Test 11 not included because measuring device failed.

[2] Measuring device failed.

20 to 30 percent of the water reaching the ground was in concentrations of 1 gallon or more per 100 square feet. Apparently, wind direction and velocity is the most important factor affecting percent of water reaching the ground in a useful pattern.

Relatively high concentration was obtained when a 40-gallon load was dropped in 1 pass as compared with a 125-gallon load dropped in multiple passes. In making more than one pass with a capacity load, the manually operated outlet gate was only partially opened for each pass because it could not be closed against a full-stream discharge. As a result, only about half of the water reached the ground in measurable quantity. More rapid release of water should result in greater concentrations for all sizes of loads.

In medium and light brush there was no significant difference between the amounts of water received at the crown and on the ground. In heavy brush, however, there was considerable variation -- from 20 to 90 percent as much water reaching the ground as was received at crown level.

Results from the retardant tests were similar to those obtained with plain water. However, the heavy sodium-calcium borate suspension, weighing 10 pounds per gallon, did not disperse as readily as water (fig. 4) and had a smaller distribution pattern (table 2) with particularly heavy concentration in the center. All of the measuring cans in the center of the pattern were tipped over by the retardant. Penetration into heavy brush was more uniform than with water; 45 to 60 percent of the amount received at the crown level reached the ground. The standing brush was well coated with retardant.

CONCLUSIONS AND RECOMMENDATIONS

These limited tests have shown that water or chemical dropped free-fall from small airplanes can have significant effect on small grass and brush fires, or on some parts of large ones. To obtain the greatest concentration of liquid on the ground, the airplane should fly as low and as slowly as conditions permit and as nearly into the wind as possible. The more rapidly water is released, the greater the concentration will be. Increasing the altitude or airspeed or dropping in a crosswind will give greater area coverage but will reduce concentration.

As with all specialized tools, the aircraft used for aerial tankers must be in top mechanical condition. Also, pilots must be

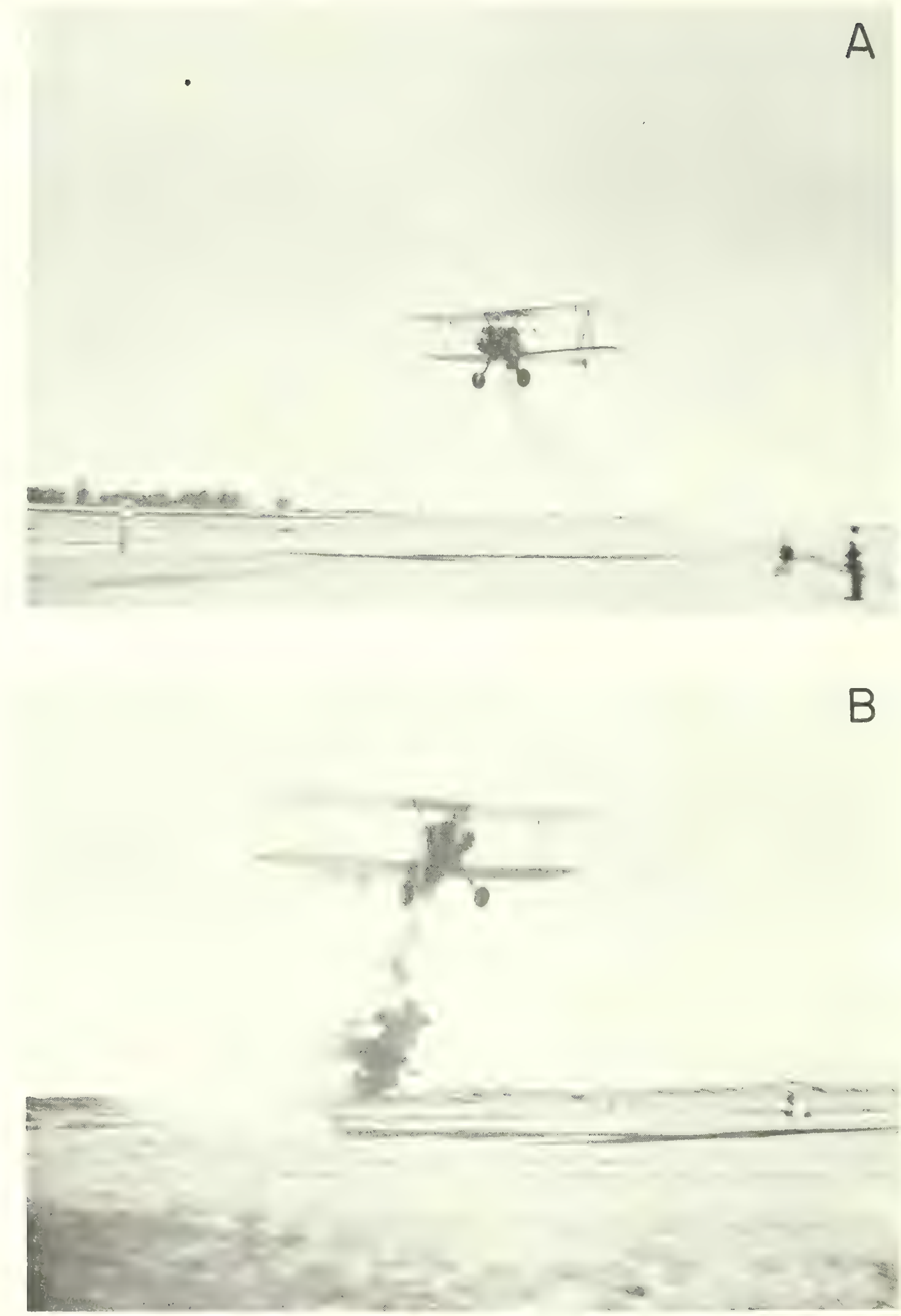

Figure 4.--Dropping water and retardant; note difference in break-up of the liquid A, water; B, retardant.

experienced both in flying under mountain conditions and in low level air drops. Pilots are cautioned to watch for sudden jumps when releasing large amounts of water. They should avoid a taildown plane attitude when dropping from low heights to minimize effects of slipstream on the water.

One aerial tanker has been of significant assistance to ground crews on fires. Indications are that several planes used in quick succession will not only be more efficient but may be able to hold temporarily short pieces of hot fire line. It is not necessary to evacuate the target area as uncontained water drops from this aircraft are not dangerous to personnel.

Considerable work still needs to be done before the aerial tanker can become a common fire fighting tool. The optimum speed, altitude, direction of flight, and method of releasing the water or chemical for each tactical situation need to be determined. Information is needed on the amount of water or chemical required to affect fires under different fuel and burning conditions. More test drops should be made under a greater variety of weather and fuel conditions, particularly at wind velocities greater than those encountered in these tests. A means of closing the outlet gate against a full stream of water is needed to permit higher concentrations of water than are now possible in multiple-pass drops. Ground-to-air communication should be improved for better tactical use.

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FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 100
November 21, 1955

EFFECT OF STORAGE TEMPERATURE ON VIABILITY OF SUGAR, JEFFREY, AND PONDEROSA PINE SEED

By
Gilbert H. Schubert, Forester,
Division of Forest Management Research

The effect of storage temperature on the viability of sugar, Jeffrey, and ponderosa pine seed was studied to determine a suitable condition for each of the three species. Barton[1] has reported -4° C. (25° F.) as being better for ponderosa pine than either -11° C. or -18° C. (12° F. or 0° F.), but storage temperatures have not been recommended for either sugar or Jeffrey pine seed. Before 1952, all seed stored at this Experiment Station was kept in air-tight containers at 41° F. (5° C.). However, germination tests on some seed lots, particularly sugar pine, indicated that storage at 41° F. might not be the optimum temperature for all species. Results of the present storage test indicate that seeds of all three pines maintain higher viability when stored at temperatures lower than 41° F. and that the optimum temperature differs for each.

Methods

The seeds for this study were collected during September 1952. After the seeds were air-dried a sample of each species was used to determine the moisture content. The moisture contents, as a percent of oven-dry weight, were: Sugar pine, 9.5; Jeffrey pine, 5.4; and ponderosa pine, 5.1. Four half-gallon cans with tight lids were filled with seeds of each species. One can of seeds of each was placed in storage at 0° F., 23° F., 32° F., and 41° F.

Germination tests were conducted with fresh seed in the spring of 1953 and with stored seed in the summer of 1955. In 1953, 2 representative samples of 250 seeds of each species were stratified in moist vermiculite in gallon cans for 3 months at 36° F. In 1955, 2

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[1] Barton, Lela V. 1954. Effect of subfreezing temperatures on viability of conifer seeds in storage. Boyce Thompson Inst. Contrib. 18: 21-24, illus.

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representative samples of 250 seeds from each storage temperature for each species were similarly stratified except that they were left in stratification for 5 months. The longer stratification period for the stored seed was necessary because of insufficient germinating flats. Therefore, the seeds were held in stratification an additional 2 months until the flats in use became available.

Germination counts were made at weekly intervals and continued until no further germination occurred. As the seedlings were counted, they were pulled out of the flats, examined, and then discarded.

Results

The germinative capacities of the fresh seeds were: Sugar pine, 98 percent; Jeffrey pine, 93 percent; and ponderosa pine, 86 percent. Most of the seed germinated during the first week--sugar pine, 90 percent; Jeffrey pine, 75 percent; and ponderosa pine 80 percent. By the end of the second week all of the sugar and ponderosa pine and 87 percent of the Jeffrey pine seed had germinated. The remaining 6 percent of the viable Jeffrey pine seed continued to germinate during the next 4 weeks.

At the time the stored seeds were removed from the 5-month stratification, most of the sugar pine seed which had been stored at 32° F. and lower had germinated. Some of the Jeffrey pine seed but very few of the ponderosa pine seeds also germinated while in stratification. The pregermination percentages were:

Storage temperatures:	Sugar pine	Jeffrey pine	Ponderosa pine
0° F.	86	21	4
23° F.	80	22	1
32° F.	66	20	1
41° F.	3	21	2

Most of the remaining seeds germinated during the first week, and all viable seeds of all three species had germinated by the end of the fourth week. The final germination percentages were:

Storage temperatures:	Sugar pine	Jeffrey pine	Ponderosa pine
0° F.	94	91	76
23° F.	84	93	78
32° F.	77	85	85
41° F.	6	84	76

The sugar pine seeds stored at 41° F. were covered with a thin layer of mold at the time they were removed from storage. After stratification both samples of these seeds were covered with a thick layer of mold and were all matted together. None of the sugar pine seed stored at the three lower temperatures, nor any seed of the other two species became moldy during the study period.

Sugar pine seed stored at 0° F., and possibly at 23° F., may not require as much as 3 months stratification to produce satisfactory germination. At the time the stored seeds were prepared for stratification, it was noted that the sugar pine seed stored at 0° F. were covered with small ice crystals. After the seeds had thawed at room temperature (approximately 70° F.), a few seeds were cut open. All endosperms and embryos were plump and moist. Therefore, a representative sample of 190 seeds were sown directly in a germinating flat without stratification. Since only 8 seeds germinated during the first 4 weeks, the flat was placed in the 36° F. refrigerator for 1 month. Within 2 weeks after removal from the refrigerator, 93 percent of the seeds germinated.

Summary and Discussion

Seeds of sugar, Jeffrey, and ponderosa pine were stored in half-gallon cans with tight lids at 4 temperatures--0° F., 23° F., 32° F., and 41° F. Best results were obtained for sugar pine at 0° F., for Jeffrey pine at 23° F., and for ponderosa pine at 32° F. Sugar pine seed stored at 41° F. lost almost all viability; however, for the other two species the difference between the best germination and that at 41° F. was only 9 percent. A heavy formation of mold on the sugar pine stored at 41° F. may be indicative of a too-high moisture content for seeds stored at that temperature.

Although not a part of the designed test, a stratification period of 5 months at 36° F. was found to be too long for both sugar and Jeffrey pine seeds. Approximately 90 percent of the viable sugar pine and 24 percent of the Jeffrey pine seed germinated while in stratification. Pregerminated seeds are unsuitable for direct seeding in the field or for sowing in the nursery because the radicles are too easily broken in handling the seed. A separate test indicated that sugar pine seed stored at 0° F. may require only a 1-month, rather than the usual 3-month stratification to produce satisfactory germination.

Further tests on the same seed lots will be continued in the 5th and 10th year of storage to determine the effects of storage temperatures after longer storage periods.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 101
December 9, 1955

DON'T PLANT CLOSE TO UNBARKED LOGS!

D. F. Roy, Forester,
Division of Forest Management Research

Instructions for planting forest trees usually stress the importance of placing them in spots which will be shaded at least part of the day. The shady sides of logs and stumps often are cited as examples of good planting spots. Observations in the California Douglas-fir type suggest that such spots are not desirable. Three years after logging the bark on cull logs begins to slough off in large patches and smothers seedlings nearby (fig. 1).

The area where bark may fall is a strip close to the log. It varies in width depending upon the diameter of the log, as shown by a few sample measurements:

Log dia. (inches)	Width of strip (feet)
30	4
35	4½
40	5
45	6
50	6½
55	7
60	8
65	8½
70	9

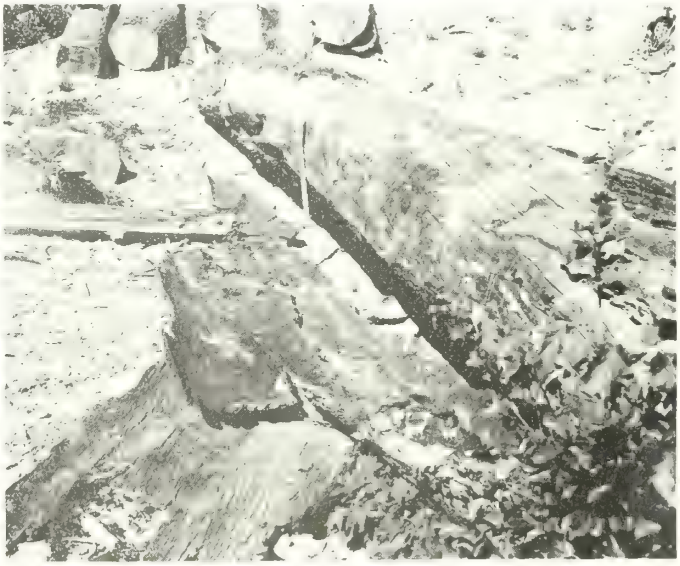

Figure 1.--Douglas-fir cull log showing large patch of bark which sloughed off 3 years after logging.

Seedlings killed by sloughing bark are not numerous enough to cause plantation failure. However, falling bark is one of several causes which decimate planted trees. To enhance planting success, planters must recognize and avoid such danger spots.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 103 January 3, 1956

FIRE SEASON SEVERITY IN 1955 ON THE KLAMATH NATIONAL FOREST

Clive M. Countryman, Forester,
Division of Forest Fire Research

Forest fires in 1955 burned over more land in northern California than in any other fire season in recent history. Much of this area was burned in two weeks of extremely severe fireweather in late August and early September. During this time, the Haystack fire alone swept over more than 64,000 acres on the Klamath National Forest. What were the burning conditions that led to the disastrous Haystack and other large fires of this period? Analysis of the daily fire danger on the Klamath National Forest shows that the extreme conditions in early fall climaxed a fire season already marked by unusually severe burning conditions.

Measurement of Burning Conditions

Fire danger ratings compiled daily on the national forests of California[1] can be used as a measure of burning conditions. These numerical ratings are proportional to the forward rate of spread of fire for observed conditions of wind velocity, temperature, humidity, and moisture content of fine fuels. In fuel types where large-sized fuels are important, the rating is adjusted to include the effect of the moisture content of these fuels on rate of spread and fire intensity. Thus in timbered areas, such as most of the Klamath National Forest, both the daily fire weather and moisture content of large fuels must be considered in evaluating the severity of burning conditions.

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[1] U.S. Forest Service, California Region. Fire Danger Rating, 11 pp. plus appendix. 1955.

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Daily Fire Danger

As a measure of the severity of the daily fire weather in different years, the fire danger ratings before adjustment for moisture content of large fuel were cumulated for July, August, and September. The totals (table 1), show that the daily fire danger in 1955 ranked near or at the top in all of the timbered areas. In contrast, the fire season of 1948--generally considered an "easy" fire year--ranked near or at the bottom for all areas.

Table 1.--Cumulated fire-danger ratings for rating areas on the Klamath National Forest, 1945-1955

Year	Fire-danger rating area and station						
	Area 1 Yreka	Area 2 Fort Jones	Area 3 Happy Camp	Area 4 Sawyers Bar	Area 5 Callahan	Area 6 Happy Camp	Area 7 Mt. Hebron
1945	-	3,256	2,885	2,925	2,634	2,885	1,031
1946	2,409	2,734	2,394	2,672	2,348	2,394	1,112
1947	2,813	2,835	2,264	2,591	2,074	2,264	1,075
1948	2,366	2,493	2,442	2,248	2,235	2,442	942
1949	2,846	2,849	2,829	2,649	2,336	2,849	1,181
1950	2,754	2,804	2,881	2,863	2,798	2,804	1,018
1951	3,010	2,823	2,989	3,213	3,081	2,823	1,153
1952	2,693	2,746	3,043	2,771	2,775	2,746	1,033
1953	2,604	2,633	2,430	2,943	2,579	2,633	992
1954	2,639	2,707	2,611	2,644	2,442	2,707	1,148
1955	3,053	2,988	2,861	3,070	2,562	2,988	1,113

Note: Areas 1 to 6 are classified as timber fuel types. Area 7 is a grass fuel type.

Moisture Content of Large Fuels

The moisture content of the large fuels at any time during the fire season depends upon the amount of moisture in the fuels at the beginning of the season and the amount they have dried during the season. In the danger rating system, these conditions are expressed by two indexes. One is a "precipitation index" derived from the amount of precipitation received at selected stations during the winter and spring months. This index is used as a measure of the moisture content of the large fuels at the beginning of the fire season. A high precipitation index indicates wet fuels and a low index indicates relatively dry fuels. The other index is a "drying index" computed from the deviations in moisture content of fuel-moisture indicator-sticks. Large plus values indicate poor drying conditions, with the large fuels drying slowly from their starting moisture content. Large negative values indicate good drying conditions resulting in rapid drying of the large fuels.

In timbered areas, the character of the fire season is closely associated with these indexes. In the easy fire year of 1948, for example, the precipitation index for the Yreka area was moderately high, and the drying index reached its highest plus value for the 1945-1955 period (fig. 1). Large fuels in this year, then, started the season at a high moisture content and dried slowly so that moisture content of these fuels remained relatively high throughout the entire season. In contrast, the precipitation index in 1949 was low and the drying index reached a large negative value. Thus large fuels started the season relatively dry and dried more than usual during the summer. The effect of the low moisture content of large fuels on fire behavior was partly responsible for the 1949 season being considered one of the most difficult of recent years.

In 1955, both the precipitation index and drying index were at the minimum for the 11-year period. This indicates that the large fuels started the season with exceptionally low moisture content and become abnormally dry during the season. Such conditions would lead to extremely hot-burning and rapid-spreading fires.

Fire Season Severity

How the average number and size of fires vary with the fire danger rating has been determined for northern California.[2] By combining these relationships a "potential" for burned area can be computed for any level of fire danger. If this potential is computed for each day's level of fire danger in a locality, the sum of these daily potentials provides a good measure of the burning conditions that have existed over the fire season, and relative severity of fire seasons can be determined by comparing seasonal totals.

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[2] Countryman, C.M., and Intorf, P.H. A Fire Season Severity Index for California. California Forest and Range Expt. Sta. Misc. Paper 14. 7 pp. 1953.

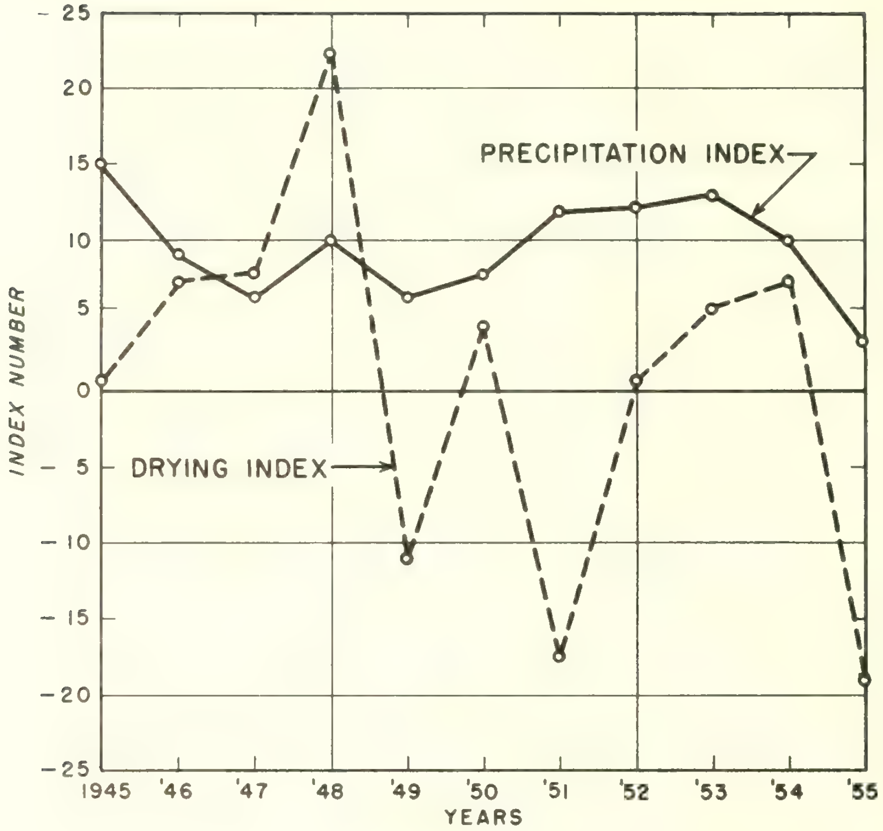

Figure 1.--Precipitation and drying index for fire danger rating Area 1 (Yreka), Klamath National Forest, 1945-1955.

Fire season[3] potentials were computed for one fireweather station in each of the fire-danger rating areas on the Klamath Forest for the years 1945 to 1955. To give a uniform base for comparison, an average seasonal potential was computed for each area by assuming that the mean fire danger occurred every day. The ratio of the total for each season to this average seasonal total was used as a "fire season severity index".

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[3] July, August, and September only.

In all of the timbered areas, the severity indexes showed the 1955 season to be the worst of the 11-year period (table 2). For example, the 1955 season at Yreka with an index of 2.95 was more than 1.7 times as severe as the previous high year of 1949 and nearly 4.5 times as severe as the easy year of 1948.

Table 2.--Fire season severity indices for fire danger rating areas on the Klamath National Forest, 1945-1955

Year	Fire-danger rating area and station						
	Area 1 Yreka	Area 2 Fort Jones	Area 3 Happy Camp	Area 4 Sawyers Bar	Area 5 Callahan	Area 6 Happy Camp	Area 7 Mt. Hebron
1945	--	1.95	0.94	1.15	1.32	0.79	1.47
1946	0.70	1.43	0.74	1.13	1.00	0.58	1.76
1947	1.35	1.32	0.49	0.97	0.58	0.45	1.32
1948	0.67	0.84	0.78	0.57	0.81	0.41	1.16
1949	1.72	1.51	1.91	1.49	1.07	1.44	1.63
1950	1.32	1.40	1.21	1.13	1.34	1.00	1.13
1951	1.30	1.33	1.88	1.86	2.05	1.54	1.46
1952	0.76	0.97	1.09	0.87	1.29	0.96	1.15
1953	0.65	0.86	0.68	0.78	1.01	0.59	1.01
1954	1.10	1.11	0.73	0.79	1.24	0.71	1.64
1955	2.95	3.31	2.24	3.10	2.08	1.83	1.53

Note: Areas 1 to 6 are classified as timber fuel types. Area 7 is a grass fuel type.

Most of the area burned on the Klamath National Forest in 1955 resulted from fires during the unusually severe fire weather in late August and early September. However, this extreme period was only partly responsible for the year's high severity index. Cumulative severity indices computed by 5-day periods for the Yreka area (fig. 2) show that by August 25 the severity index already exceeded that for the entire season of 1949, the worst previous year. As early as July 27, 1955, the cumulative index had equaled that for the entire 1948 season. Even then, the extreme fire weather in late August and early September increased the severity index materially, as is shown in figure 2 by the sharp increase in slope of the 1955 curve during this period.

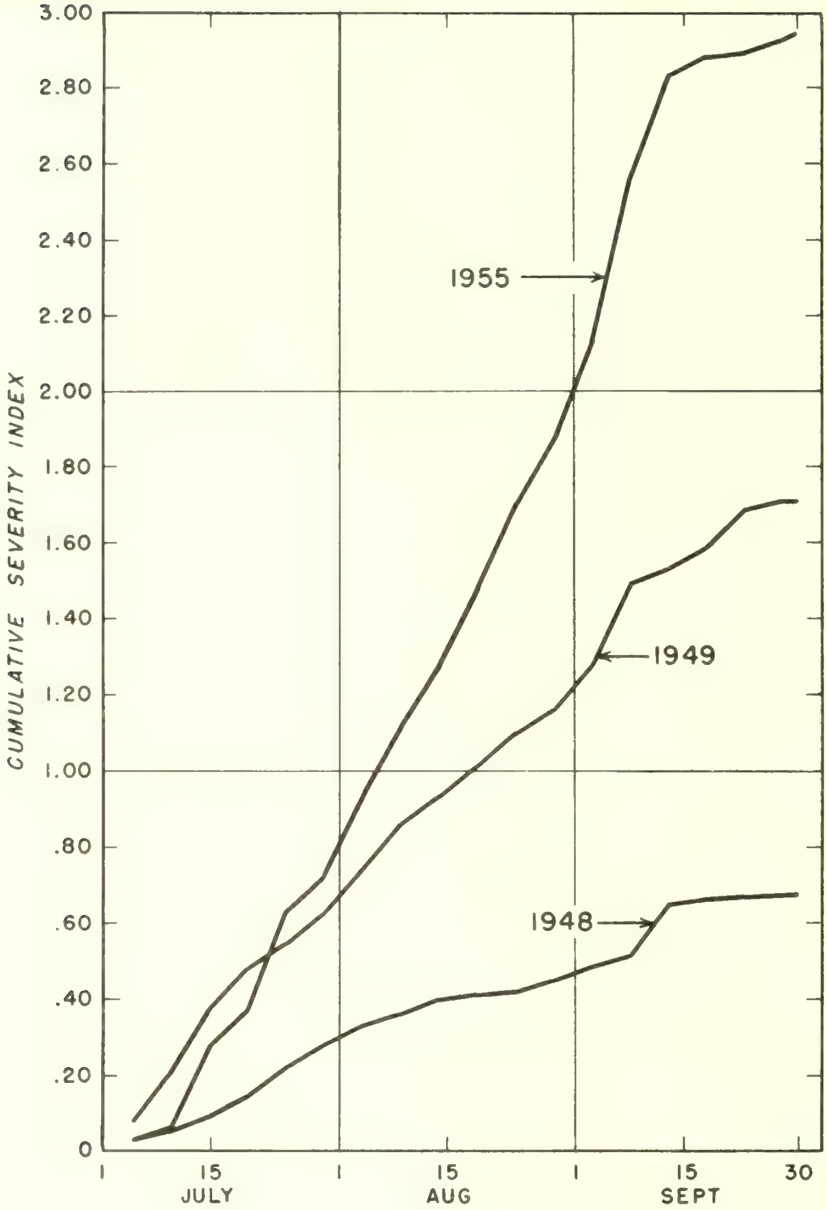

Figure 2.--Cumulative severity index by 5-day periods for Area 1 of the Klamath National Forest.

The severity of the 1955 fire season appears to be the result of abnormally low winter and spring precipitation, a favorable season for drying of large fuels, and severe fire weather--all occurring in the same year. Yet, a more severe season is possible. The precipitation index in the Yreka area for example, was 3.4 in 1955. Lower indexes occurred in 1924 (1.7) and in 1926 (3.0). A precipitation index of 1.7 in 1955 with all other conditions being the same would have resulted in a severity index of 4.46 instead of 2.95. Lower drying indices than that for 1955 are possible, and daily fire weather has been more severe in some fire danger rating areas. New extremes of these factors occurring simultaneously would result in an even greater potential for a disastrous fire year.

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
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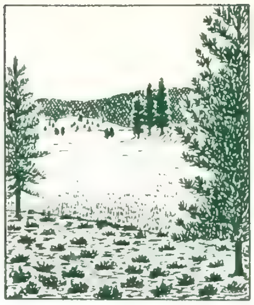

No. 104

April 16, 1956

PLANTING PONDEROSA PINE IS A GOOD INVESTMENT

William E. Hallin, Forester,
Division of Forest Management Research

Is planting forest trees a good investment? This is a pertinent question in California because of the need for well stocked forest lands to maintain forest industry and the lack of natural regeneration on large acreages of land best suited to timber production. To help answer the question for operating forest properties, we have determined what the present worth of future timber harvests would be at the time ponderosa pine plantations were established. The analysis was based on the following five assumptions:

1. The ponderosa pine yield tables[1] give reasonable estimates of the expected volumes per acre for fully stocked managed stands even though the size and number of trees will differ from the yield table data.

2. The utilization standards specified in the yield table for the stand 6.6 inches in diameter and larger (International 1/8-inch rule) will be realized.

3. The diameters attained in managed stands will be greater than in wild stands owing to more rapid growth after intermediate harvest cuts.

4. Stumpage prices will at least equal those shown in table 1.

5. A reduction of 25 percent in yields or receipts will provide an adequate allowance for adverse factors such as incomplete stocking and unsalvageable mortality.

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[1] Meyer, Walter H. 1938. Yield of even aged stands of ponderosa pine. U. S. Dept. Agr. Tech. Bul. 630, 59 pp., illus.

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To determine yield from the plantation, the average diameter in the stand was estimated for selected site indexes and age classes (table 1). Diameter estimates were based on data from wild stands,[2] thinning studies, and other growth studies. For the youngest age on each site, the diameter is the expected average diameter of the leave trees; for all other ages it is the expected average diameter of both cut and leave trees. The expected number of trees per acre for all ages except the youngest on each site was computed by dividing the yield table volume per acre by the volume of a tree of the estimated diameter.

In estimating the volume of the intermediate harvests it was reasoned that all but the computed number of trees for the next age would be cut. Intermediate harvests are a significant part of the assumed method of management. They reduce the investment, increase total yield by salvaging many trees that would die before the final harvest, and encourage faster growth on the remaining trees.

The present worth of the intermediate and final yields (table 2) was computed by use of appropriate compound interest tables. Besides the 25 percent allowance for adverse factors, the cost of pruning selected crop trees, discounted to the time of planting, also was subtracted from the total value. On managed forest properties most fixed and current operating costs, for example, for roads and fire protection, are not increased as a result of improving the stocking by planting. Consequently the direct outlays for planting and pruning, and the interest charges against them, are the only charges that need to be assessed against the plantation yields. Therefore the data in table 2 show the maximum amounts that can be spent for planting and site preparation and still earn the indicated interest rates.

As an example, planting cost can be taken as $70 per acre. This is about the average for planting stock, site preparation, and setting out the trees in the pilot-plant operation at Blacks Mountain Experimental Forest. At $70 per acre, planting ponderosa pine would yield an interest rate of 6 percent for site A-200, 5 percent for site I-175, 4 percent for site II-150, 3 percent for site III-125, and less than 2 percent for site IV-100. The breaking point for 2 percent is between sites III-125 and IV-100.

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[2] List of material. Forest Management Field Course. Unpublished report by Duncan Dunning, California Forest and Range Experiment Station, July 1, 1951.

Table 1.--Basic data used in analysis of planting investment

Age (Years)	Site index 60			Site index 70			Site index 80		
	Average d.b.h.	Volume cut per acre	Stumpage per M	Average d.b.h.	Volume cut per acre	Stumpage per M	Average d.b.h.	Volume cut per acre	Stumpage per M
	Inches	Bd.-ft.	Dollars	Inches	Bd.-ft.	Dollars	Inches	Bd.-ft.	Dollars
50	8	[1] 1,085	10	9	[1] 2,955	10	10	[1] 3,850	10
60	10	1,290	20	11	3,120	20	12	5,220	20
80	13	2,640	20	15	2,800	20	16	7,280	20
100	16	1,820	20	18	4,680	30	20	31,200	40
120	19	2,870	30	21	27,700	40	--	--	--
140	22	24,400	40	--	--	--	--	--	--
	Site index 100			Site index 120			Site index 140		
30	--	--	--	--	--	--	9	[1] 17,075	10
40	9	[1] 9,770	10	10	[1] 20,610	10	14	23,320	20
60	15	11,280	20	18	17,500	30	22	18,800	30
80	20	40,200	40	24	62,200	40	28	88,700	40

[1] Calculated in cords and converted to board-feet at the rate of 2 cords per M board-feet.

Table 2.--Present value[1] [2] per acre of intermediate and final harvests of ponderosa pine plantations

Site index[3]	Present value at indicated interest rate 2%	2½%	3%	4%	5%	6%	Rotation
	Dollars						Years
60 (IV-100)	65	35	--	--	--	--	140
70	114	67	46	19	--	--	120
80 (III-125)	177	113	73	31	--	--	100
100 (II-150)	323	225	158	78	40	--	80
120 (I-175)	--	394	279	143	75	40	80
140 (A-200)	--	--	468	257	146	86	80

[1] Reduced by charges for pruning selected crop trees at the rate of 50 cents per tree, discounted to the present.

Site index 60: 40 trees at 50 years = $20 per acre;
70 and 80: 40 trees at 40 years = $20 per acre;
100 and 120: 50 trees at 30 years = $25 per acre;
140: 50 trees at 20 years = $25 per acre.

[2] Full earnings reduced 25 percent to take care of incomplete stocking and unsalvageable mortality.

[3] Site index at 100 years -- ponderosa pine yield table. Symbols in parenthesis indicate site quality according to Dunning, "A site classification for the mixed-conifer selection forests of the Sierra Nevada," California Forest and Range Experiment Station Research Note No. 28, 21 pp. (Processed). Dec. 1, 1942.

The interest rate used is perhaps the most important factor in determining present worth of plantation yields. Decreasing the interest rate by 1 percent approximately doubles the present worth at the time of planting. The stumpage price would have to be about doubled in order to make the same change in the present worth. Consequently, selection of an acceptable minimum interest rate is highly important in deciding whether or not to invest money in planting. The probable earnings on alternate long-term investments available to the land owner are the best guide. High earnings on stocks not available for purchase or subject to wide fluctuation obviously are not good guides for determining acceptable long-term interest rates. For example, the Federal government frequently borrows money at 2 percent. Therefore selection of a 2 percent rate for planting on national-forest land is appropriate. An important point to keep in mind is that young trees continue to grow regardless of economic ups and downs. Possible indirect values--such as in public relations, extension of employment for seasonal workers, and the assurance of future sources of raw material for large plants--may also influence the decision regarding the acceptable interest rate.

Then what is the answer to the question, "Is planting a good investment?" On the basis of this analysis, planting the better quality sites appears to be a good investment for almost any forest owner in California. On the lower sites planting is a good investment only for those who can and are willing to accept low rates of earnings.

No matter what interest rate is chosen, however, the planting and site preparation must be well done. Saving money in these jobs is pointless if too few trees are established to return the expected yields.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 106 April 20, 1956

KILLING TANOAK IN NORTHWESTERN CALIFORNIA

D. F. Roy, Forester,
Division of Forest Management Research

Introduction

Residual tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.) trees and tanoak sprouts often are an important component of the vegetation which competes with conifer reproduction in northwestern California. Sometimes enough tanoak is present in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands to dominate the ground completely after logging. And tanoak sprouts develop vigorously after parent trees are destroyed by fire or logging (fig. 1), thereby providing severe competition to conifer reproduction.[1] Although tanoaks generally are considered undesirable at present, someday they may contribute substantially to forest products. Large tanoaks with good form and limb-free boles are common on better sites. The wood has good properties, a pleasing appearance and, although considerable care is required in seasoning, additional experiments should develop practicable drying schedules. Tanoak has produced veneer and pulp of good quality and yield. The bark contains tannin which is particularly desirable for tanning sole and saddle leather. For these reasons tanoak should not be killed promiscuously but only when it interferes with the objectives of management.

Preliminary experiments in 1952 and 1953 tested the feasibility of eliminating tanoak with herbicides. Larger trees were treated in one trial and young sprouts were sprayed in the other.

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[1] Roy, D. F. Hardwood sprout measurements in northwestern California. Calif. Forest and Range Expt. Sta. Res. Note 95. 6 pp., illus. 1955.

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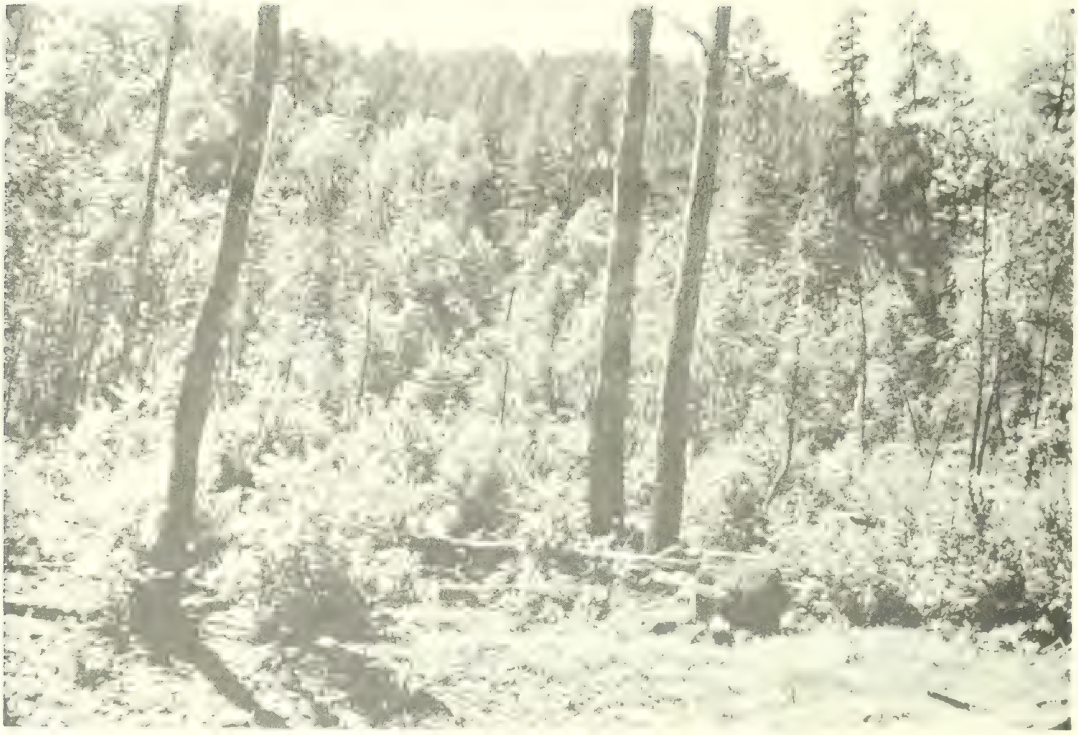

Figure 1.--Tanoak sprouts and residual tanoak trees 4 years after logging a thinly stocked stand of Douglas-fir (2,245 board-feet per acre). Swanson Unit, Lower Trinity Ranger District, Six Rivers National Forest.

Poisoning Tanoak Trees

The first trial attempted to kill 160 vigorous tanoak trees. Each tree was treated in one of four ways:

1. Sprayed basally with a 1 percent solution by weight of a high volatile ester of 2,4-D (2-4-dichlorophenoxyacetic acid) in diesel oil.
2. Frilled and then soaked with a 1 percent solution of 2,4-D in water.
3. Basal spray with a low volatile ester of 2,4,5-T (2-4-5-trichlorophenoxyacetic acid) in diesel oil.
4. One percent 2,4,5-T water solution applied after frilling.

Treatments were assigned at random after grouping trees of similar diameter, dominance, and vigor into blocks of four trees--one tree for each treatment. Forty trees were treated on each of the following dates: May 23, July 28, October 2, and November 6, 1952. Diameter at breast height ranged from 3 to 36 inches, averaging 12 inches, and trees were distributed in crown classes as follows: Dominant--33 percent; codominant--18 percent; intermediate--28 percent; and suppressed--21 percent. All trees had vigorous crowns with full, healthy foliage.

Results

Effects were slight at first. At the end of the first growing season after treatment, a 3-inch tree treated with the 2,4-D basal spray died, and 85 percent of the trees treated May 23 and July 28 with 2,4,5-T in diesel oil appeared to be dying. Some of the latter partially recovered the next spring.

A more general reduction in vigor became evident by the end of the second growing season after treatment and has continued through the fourth year (table 1, fig. 2). The diesel oil solution 2,4,5-T was the most effective killer (30 percent kill at the end of the fourth growing season) and also reduced tree vigor more than other treatments through the third growing season. Some of the trees receiving this treatment, however, began to recover during the fourth season. For the frilled trees there was a large drop in vigor between the third- and fourth-year examinations. The mechanical injury to the phloem by frilling probably had substantially more effect than the two different herbicides in water, although the herbicides have prevented sprouting. The 2,4-D in diesel oil was much less effective than the other treatments. The experiment will be maintained to determine the fate of the trees which are still living.

The test of time of treatment did not produce statistically significant differences. Results do show that tanoaks with smaller diameters were killed more easily by poisoning regardless of treatment or crown class (table 2).

Stronger concentrations (4 or 5 percent solutions by weight) of herbicides should be used in future attempts to kill tanoak trees quickly. A basal spray of 2,4,5-T in diesel oil appears most likely to succeed. Girdling alone, however, may also be useful for treating trees on areas where nurse trees are desired to ameliorate the site until conifer reproduction becomes established. The tanoaks would provide shade to young conifers in decreasing amounts as tree vigor and crown density decrease each year after girdling until the tanoaks die.

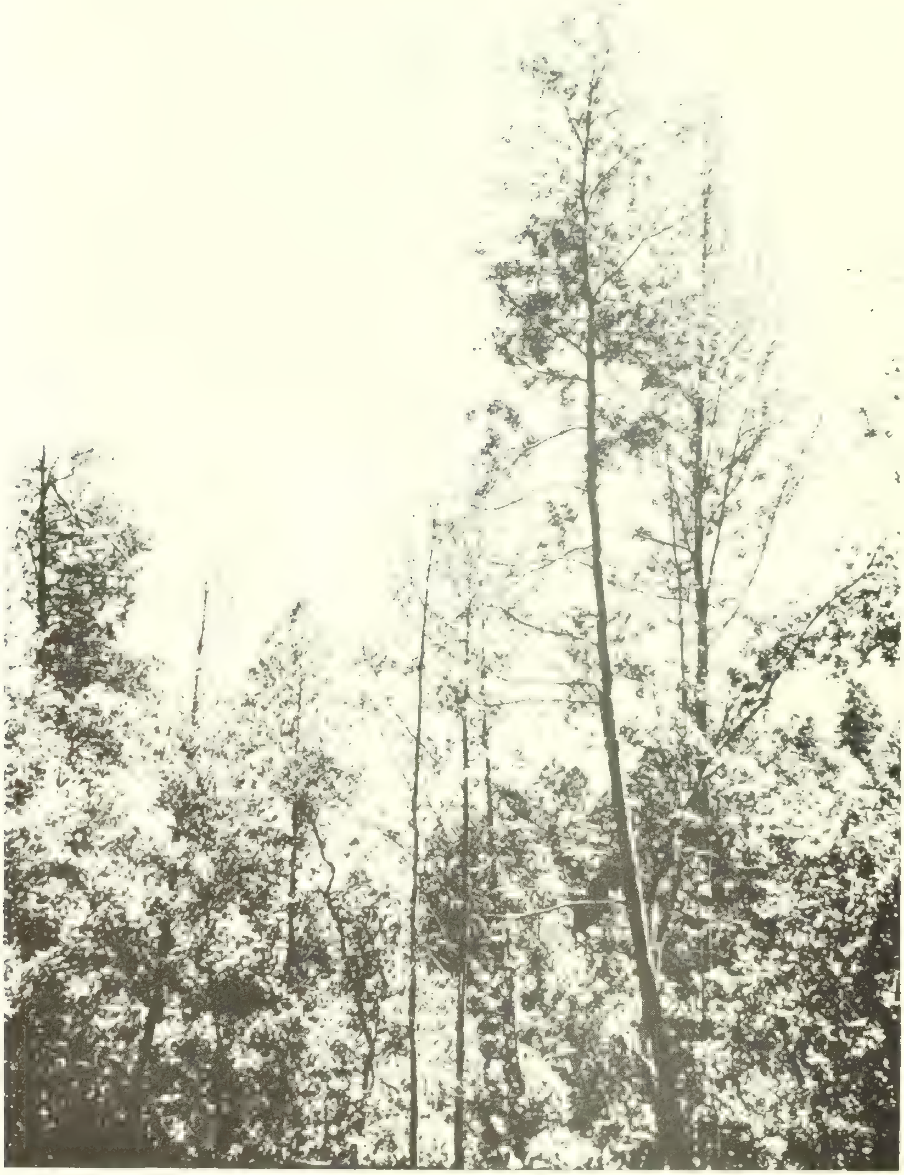

Figure 2.--Crowns of poisoned tanoak trees 4 years after treatment. The thickly leafed crowns of the originally vigorous trees have been drastically thinned. However, a few of the basally sprayed trees, such as the one in the right foreground, seem to be recovering. Swanson Unit, Lower Trinity Ranger Station, Six Rivers National Forest.

Table 1.--Vigor of tanoaks 2, 3, and 4 years after poisoning by 4 different methods (Six Rivers National Forest, test of 1952)

Vigor class	2,4-D (high volatile ester)		2,4,5-T (low volatile ester)		
	Diesel oil	Water and frilling	Diesel oil	Water and frilling	All
	- - - - - - - - Percent	- - - -	- - - -	- - - -	- - - -
After 2 years:					
Vigorous	65.0	57.5	22.5	62.5	51.9
Medium	20.0	32.5	12.5	22.5	21.9
Poor	7.5	5.0	47.5	10.0	17.5
Dead	7.5	5.0	17.5	5.0	8.7
Total	100.0	100.0	100.0	100.0	100.0
After 3 years:					
Vigorous	42.5	5.0	15.0	10.0	18.1
Medium	30.0	57.5	17.5	55.0	40.0
Poor	12.5	27.5	40.0	27.5	26.9
Dead	15.0	10.0	27.5	7.5	15.0
Total	100.0	100.0	100.0	100.0	100.0
After 4 years:					
Vigorous	30.0	0.0	10.0	0.0	10.0
Medium	32.5	7.5	30.0	25.0	23.8
Poor	22.5	82.5	30.0	67.5	50.6
Dead	15.0	10.0	30.0	7.5	15.6
Total	100.0	100.0	100.0	100.0	100.0

Table 2.--Average diameters of tanoaks by vigor and poisoning treatments, and by vigor and crown classes, four growing seasons after treatment (Six Rivers National Forest, test of 1952)

Item	Vigor class			
	Vigorous	Medium	Poor	Dead
	Inches			
Treatment				
2,4-D in diesel oil	15.4	12.4	9.3	4.9
Frilled & 2,4-D in water	--	8.5	12.6	7.8
2,4,5-T in diesel oil	11.1	17.2	11.8	6.6
Frilled & 2,4,5-T in water	--	14.2	13.2	4.9
Crown class:				
Dominant	22.4	19.5	17.3	6.9
Codominant	15.5	14.4	13.6	10.3
Intermediate	10.1	8.3	8.7	7.5
Suppressed	6.7	5.7	5.9	4.6
All	14.4	14.0	12.3	6.2

Poisoning Tanoak Sprouts

In the second trial 120 tanoak sprout clumps were sprayed with herbicides from a back-pack pump. Three different formulations were used:

1. High volatile ester of 2,4-D (isopropyl ester) in a 1.2 percent solution.

2. Low volatile esters of 2,4-D (propylene glycol butyl ether esters) in a 1.4 percent solution.

3. Low volatile esters of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid, propylene glycol (C_3H_6O to $C_9H_{18}O_3$) butyl ether esters) in a 1.4 percent solution.

Diesel oil was the carrier for all three herbicides. Solutions were sprayed to run-off on both leaves and basal parts of the sprouts.

Thirty sprout clumps--10 for each chemical--were sprayed on each of the following dates: July 1, August 25, October 14, and November 4. These clumps ranged in height from 0.7 to 5.6 feet, in diameter from 0.6 to 7.4 feet, and in number of sprouts from 1 to 162. The average clump was 2.4 feet high, 2.6 feet in diameter, and had 16 sprouts.

Results

Almost all original sprouts were killed. The only exceptions were 4 clumps sprayed July 1, where 17 percent, 7 percent, 6 percent, and 5 percent of the sprouts survived. The incomplete kill in these few cases probably was caused by failure to apply the sprays thoroughly.

Resprouting varied with the dates of application (table 3). Only one of the 60 clumps treated on or after October 14 resprouted. A few clumps sprayed on August 25 and several treated on July 1 sprouted again, but compared to the original clumps new sprout development was feeble--both in size of individual shoots and in numbers (table 4). The position of new sprouts in relation to those killed by spraying indicated that the later application of herbicides resulted in the more thorough destruction of root collars. To illustrate, sprouts which grew from parent clumps sprayed on July 1 emerged from among the dead sprouts, but new shoots developed after the treatment of August 25 grew only from the perimeter of the original clumps. And in the single instance where a sprout clump treated on October 14 produced additional sprouts, the shoots emerged from the soil at least 5 inches away from the nearest initial sprout.

Of the three chemicals tested 2,4,5-T seemed most effective in killing tanoak sprouts, followed closely by the high volatile ester of 2,4-D. The test indicated that low volatile esters of 2,4-D are slightly less potent for killing tanoak, although for other plants the low volatile esters generally have been more effective. 2/

Conclusions

Tanoak trees:

1. The low volatile ester of 2,4,5-T was more effective than the high volatile ester of 2,4-D in killing tanoak trees.

2/ Ltr. of Dec. 17, 1953 from Dr. R. N. Raynor, Agricultural Chemical Development, The Dow Chemical Company.

Table 3.--Percentage of tanoak sprout clumps producing new sprouts after spraying (Six Rivers National Forest, test of 1953)

Herbicide and date of examination		Date of application			
		July 1	Aug. 25	Oct. 14	Nov. 4
		Percent			
2,4-D (high volatile ester)					
Aug. 25	1953	20	--	--	--
Oct. 14	1953	20	0	--	--
Nov. 4	1953	20	0	0	--
June 9	1954	20	0	0	0
Sept. 3	1954	20	50	0	0
2,4-D (low volatile ester)					
Aug. 25	1953	50	--	--	--
Oct. 14	1953	50	0	--	--
Nov. 4	1953	50	0	0	--
June 9	1954	60	0	0	0
Sept. 3	1954	70	30	10	0
2,4,5-T (low volatile ester)					
Aug. 25	1953	20	--	--	--
Oct. 14	1953	40	0	--	--
Nov. 4	1953	40	10	0	--
June 9	1954	40	10	0	0
Sept. 3	1954	50	20	0	0

2. One percent solutions of 2,4-D or 2,4,5-T in diesel oil applied as basal sprays were not strong enough to kill tanoak trees effectively.

3. Effects of frilling tanoak trees were delayed, but vigor has decreased slowly and trees will eventually die. Application of weak (1 percent) solutions of 2,4-D and 2,4,5-T on frills prevented sprouting.

4. Small tanoaks were killed with herbicides easier than large trees.

5. Some tanoaks reduced to poor vigor with basal sprays of 2,4-D and 2,4,5-T began to recover during the fourth growing season after treatment.

Sprouts:

1. Tanoak sprouts were eliminated by low concentrations of either low or high volatile esters of 2,4-D and low volatile esters of 2,4,5-T.

2. Tanoak sprout clumps were killed more certainly in late fall than in July and August. Sprout clumps sprayed after mid-October did not resprout.

3. Of the three chemicals tested 2,4,5-T seemed most effective in killing tanoak sprouts.

Table 4.--Average number of new sprouts per clump for those clumps producing sprouts after spraying (Six Rivers National Forest, test of 1953)

Herbicide	Date of application July 1	 Aug. 25	 Oct. 14	 Nov. 4
2,4-D (high volatile ester)	5.0	2.6	--	--
2,4-D (low volatile ester)	12.3 [1]	5.0	9.0	--
2,4,5-T (low volatile ester)	2.6	2.5	--	--

[1] Seven out of ten sprout clumps resprouted after spraying. The average number of new sprouts per clump is high because three of the clumps produced 40, 13, and 12 new sprouts, respectively.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 107 May 21, 1956

SALVAGE LOGGING MAY DESTROY DOUGLAS-FIR REPRODUCTION

D. F. Roy, Forester,
Division of Forest Management Research

In the future the United States will need all the softwoods our forest lands can grow. [1] Yet thousands of acres in northwestern California are idle because they have not been restocked with adequate conifer reproduction after logging or burning. Scanty seedlings are not necessarily the result of negligence. Forest managers realize that reproduction often is hard to establish. Obviously, if advance reproduction is already established before cutting, every possible precaution to preserve the young trees should accompany the logging operation.

Logging damage to reproduction can be reduced by careful preparation of a logging plan and adherence to that plan. [2] But how extensively is Douglas-fir reproduction destroyed by conventional salvage logging methods on ground typical of northwestern California? To answer this question observations were recorded on a small part of the Three Creeks Burn, Humboldt County.

The fire killed almost all the standing timber on the study area in August 1951. Later that year heavy seedfall occurred from undamaged timber nearby. An excellent stocking of Douglas-fir seedlings resulted.

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[1] Crafts, Edward C. Timber Resource Review. Chapter I. Timber resources for America's future. A summary of the timber resource review. U. S. Forest Service. 129 pp., illus. September 1955.

[2] Cosens, Richard D. Reducing logging damage. Calif. Forest and Range Expt. Sta. Res. Note 82. 10 pp., illus. 1952.

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Conditions Before Logging

In 1954, before salvage logging, 2 line transects were surveyed and 103 milacre quadrats were examined. Douglas-fir seedlings were distributed on the area at the rate of 1,981 per acre, and 71 percent of the milacres were stocked with at least one seedling--enough seedlings and good enough distribution to create a satisfactory forest. The ground, a 40-percent, east-facing slope, was 95 percent covered with vegetation (fig. 1). Components of the ground cover, in approximate order of importance based upon area occupied were:

Western bracken	(*Pteridium aquilinum pubescens*)
Tanoak	(*Lithocarpus densiflorus*)
Modest whipplea	(*Whipplea modesta*)
Snowbrush ceanothus	(*Ceanothus velutinus*)
Bushmans burnweed	(*Erechtites arguta*)
Salal	(*Gaultheria shallon*)
Pacific madrone	(*Arbutus menziesii*)
Torrey peavine	(*Lathyrus torreyi*)
Cascades mahonia	(*Mahonia nervosa*)
Western trumpet honeysuckle	(*Lonicera ciliosa*)
California rose	(*Rosa californica*)
Golden chinkapin	(*Castanopsis chrysophylla*)
Grapeleaf California dewberry	(*Rubus ursinus vitifolius*)
Deerbrush ceanothus	(*Ceanothus integerrimus*)
Sedge	(*Carex*)

Although the ground was almost completely covered with competing plants, the Douglas-fir seedlings were growing well. Some seedlings were 18 inches tall and several had grown more than 11 inches in 1953. Enough seedlings were growing sufficiently fast to dominate the area eventually.

Logging removed an average of 41,800 board-feet (net) per acre. The operator, who used typical tractor logging methods, did not know that the transects existed and, therefore, was not influenced by them.

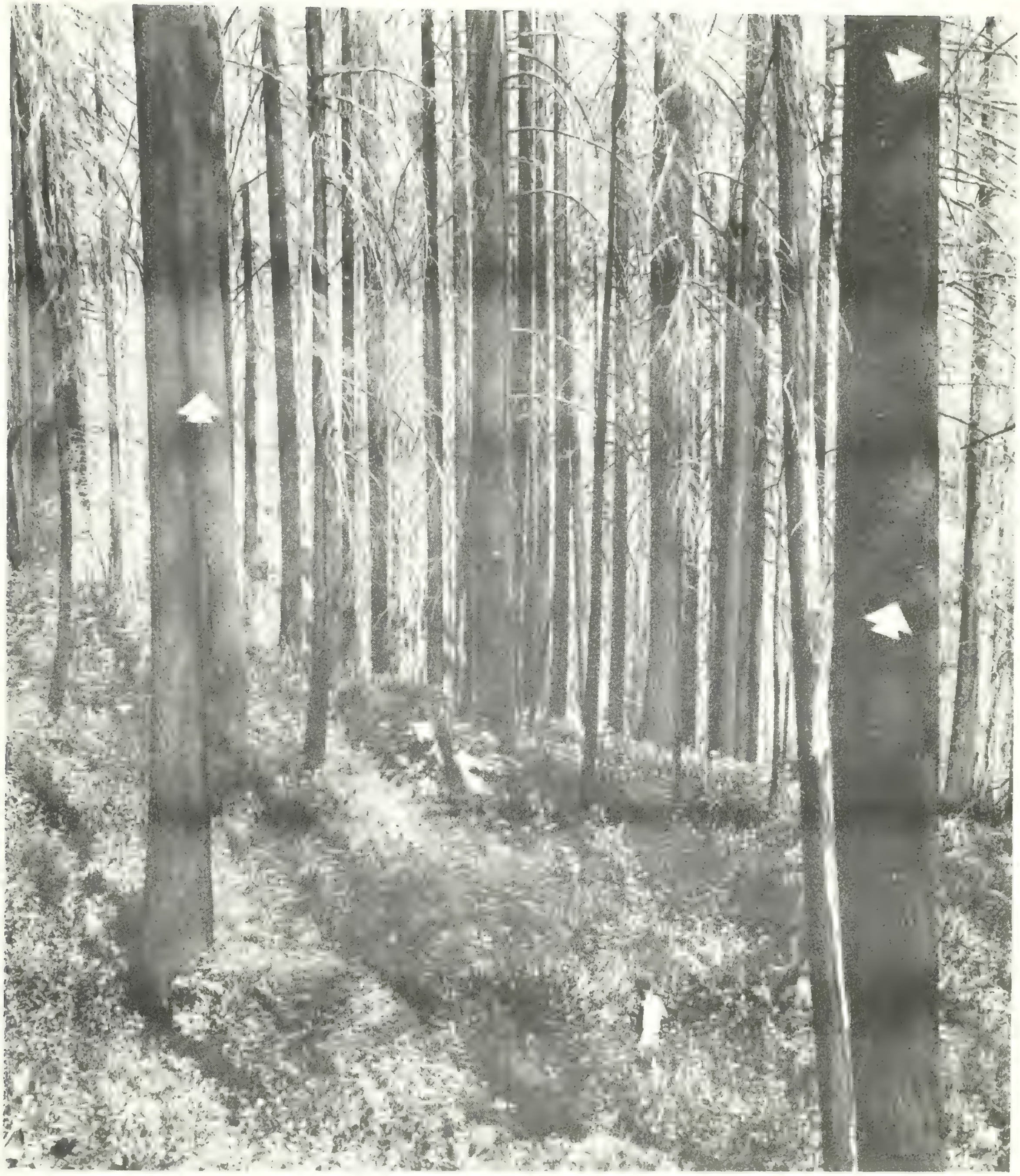

Figure 1.--Fire-killed timber and heavy ground cover before salvage logging. Three years after the fire sporophores of the pouch fungus (arrows) are numerous. Buck Butte Sale, Three Creeks Burn, Six Rivers National Forest, 1954.

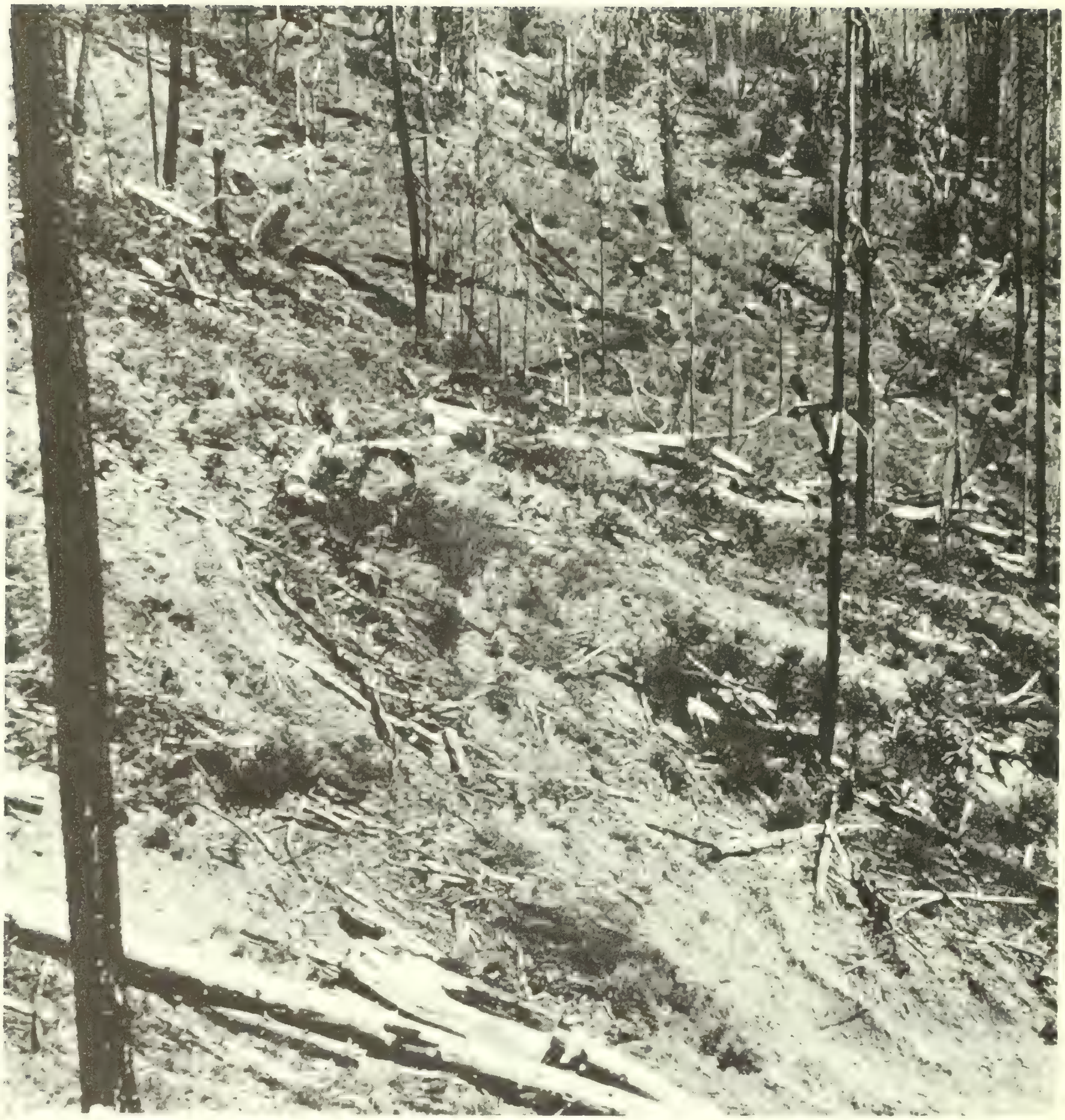

Figure 2.--Ground condition in 1955 after logging fire-killed timber on the area shown in Figure 1. A large part of the ground has been disturbed severely.

Conditions After Logging

After logging only 25 percent of the milacre quadrats remained stocked with Douglas-fir seedlings. The number of seedlings was reduced to 417 per acre. All quadrats had been disturbed by logging to some degree. Two percent were only lightly disturbed, but 34 percent were moderately disturbed and 64 percent were severely disturbed (fig. 2). Stocking on milacre plots was: Lightly disturbed, 100 percent; moderately disturbed, 51 percent; severely disturbed, 9 percent. Salvage logging, therefore, destroyed about 80 percent of the original seedlings, and the severity of seedling destruction was related to the degree of logging disturbance.

Reducing Damage to Reproduction

Can destruction of conifer seedlings be reduced under conditions similar to those found on the Buck Butte Sale? The most obvious measure is to salvage fire-killed timber immediately. Two advantages accrue. First, logging is completed before new reproduction is established, and conifer seedlings which stock the area soon after logging will have the best chance to compete with other vegetation which is also just beginning to regenerate. Second, early salvage logging prevents growth of the pouch fungus (Polyporous volvatus (Pk.), which destroys the sapwood and weakens trees, causing higher losses from felling breakage and rot.

Another way to protect reproduction is by careful logging. This demands proper training and supervision of logging crews. At first thought the possibilities for modifying logging practices to protect small seedlings appear unpromising, but attention to several seemingly minor details can save appreciable reproduction. Some of these details are:

1. Felling trees in proper directions.
2. Clean limbing before skidding.
3. Scouting out and planning each turn of the tractor.
4. Setting chokers without rolling logs with dozer blades or tractor tracks.
5. Setting chokers to roll logs away from reproduction.
6. Pulling tractor cables from the drum to the log when warranted.
7. "Breaking-out" logs in line with the original lay of the tree.

When you find good reproduction, protect it. Try to save the high costs of artificial regeneration.

FOREST RESEARCH NOTES
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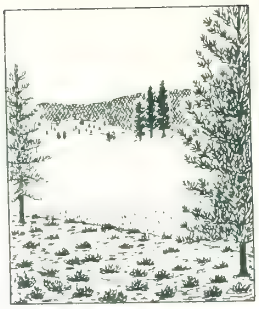

No. 109

August 15, 1956

THE EFFECTS OF PLANT COMPETITION UPON THE GROWTH AND SURVIVAL OF BITTERBRUSH SEEDLINGS [1]

Richard L. Hubbard, Range Conservationist
Division of Range Research

Many winter deer ranges throughout the West have been steadily deteriorating as a result of overgrazing, fire, and insect depredations. Lack of winter forage has caused heavy mortality of deer. The problem has become so acute that some of the western states have started research to determine what can be done to rehabilitate these ranges, if and when the causes of deterioration can be controlled.

The California program was started in the deer winter range area east of the Sierra Nevada mountains. This area extends from Oregon to the Owens Valley in Inyo County. Special attention has been given to studies of bitterbrush (Purshia tridentata), the most important winter deer browse species in the eastside region.

This paper reports on a study of the effects of competition on bitterbrush seedlings. The work was done in Modoc County on the winter range of the California-Oregon Interstate deer herd. Here, the predominant vegetation is a transition type between ponderosa pine and the sagebrush-juniper complex. Big sagebrush (Artemisia tridentata), juniper (Juniperus occidentalis), rabbitbrush (Chrysothamnus spp.), and bitterbrush make up the bulk of the

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[1] Contribution from cooperative investigation between the California Forest and Range Experiment Station and the California Department of Fish and Game. Work was done under Federal Aid in Wildlife Restoration Act, Pittman-Robertson Research Project W51R, entitled "Game Range Restoration."

The author acknowledges that this study was planned and designed by A. L. Hormay, Range Conservationist, California Forest and Range Experiment Station.

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brush cover. The understory is composed of perennial grasses and annual and perennial forbs. A few scattered ponderosa pine (Pinus ponderosa) are also present. The annual precipitation averages between 12 and 14 inches, much of it falling as snow.

Methods

In areas of relatively low precipitation, such as Modoc County study area, the most important if not the limiting factor in seedling establishment is soil moisture. It may be impractical in a range seeding program to improve soil moisture conditions by irrigation, but it is feasible to prepare seedbeds and control the vegetation that competes with seeded species for available soil moisture.

For this study of the effects of competition, three areas were selected inside a deer-livestock exclosure. One area was drilled with bitterbrush seed without soil preparation or removal of the stand of native plants. The other two were plowed, harrowed, and dragged with a rail. One of these was drilled with bitterbrush seed alone and the other with a mixture of bitterbrush and crested wheatgrass seed. Plots on the area prepared and drilled with bitterbrush alone were segregated for three different treatments. Some were kept weeded during three growing seasons, others were weeded only during the first growing season, and some were not weeded at all. The weeded plots represented negligible competition and those weeded only the first year were considered to represent light competition. The native and crested wheatgrass areas offered heavy competition. The crested wheatgrass probably did not use as much soil moisture as the established native vegetation during the first growing season. During the second and third season, however, the crested wheatgrass competed at least as heavily as native plants for available soil moisture.

To obtain indices of stored soil moisture, fiberglas soil-moisture units (Colman, 1947)[2] were installed at 1.5, 21, and 54 inches below the surface in both the plowed and weeded and the undisturbed areas. These units measure soil moisture in terms of electrical resistance. It is possible to calibrate the resistance readings with actual soil moisture percent. However, this was not done in this study. Instead, indices derived directly from weekly resistance readings were plotted to show soil moisture depletion.

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[2] Colman, E. A. 1947 (Rev. 1950). Manual of instructions for use of fiberglas soil-moisture instrument. Calif. Forest and Range Expt. Sta. 20 pp. Illus. (processed).

Results

During the first growing season, soil moisture on the undisturbed, native area was depleted rather rapidly (fig. 1). Moisture to a depth of 1.5 inches was largely used during June, and by late July most of it was taken to a soil depth of 21 inches. Even at the 54-inch depth soil moisture was heavily drained during August and September. Where plant competition was negligible, soil moisture was reasonably stable at 21 and 54 inches throughout the growing season. Even at the 1.5 inch depth, soil moisture was not depleted until mid-August, a full month later than on the undisturbed area.

The earlier and more complete depletion of soil moisture under heavy competition was reflected in bitterbrush seedling mortality and growth. Seedling mortality under heavy competition was between 57 and 60 percent during three growing seasons (table 1). Under light competition, mortality was only 21 percent. Mortality under negligible competition was essentially the same as under light competition; apparently the invading annual weeds used relatively little of the stored soil moisture.

Table 1.--Mortality through three growing seasons of bitterbrush seedlings emerging in the spring of 1953 under different levels of competition

Level of competition	July 13 1953	At end of first growing season	At end of second growing season	At end of third growing season
	- - - - - -	Percent	- - - - - -	
Negligible	17.1	21.0	22.4	22.4
Light:				
Weeded during first growing season	17.1	21.0	21.0	21.0
No weeding	17.1	20.5	20.8	20.8
Heavy:				
Crested wheat	20.5	31.2	46.5	60.0
Native vegetation	17.8	45.0	55.0	56.6

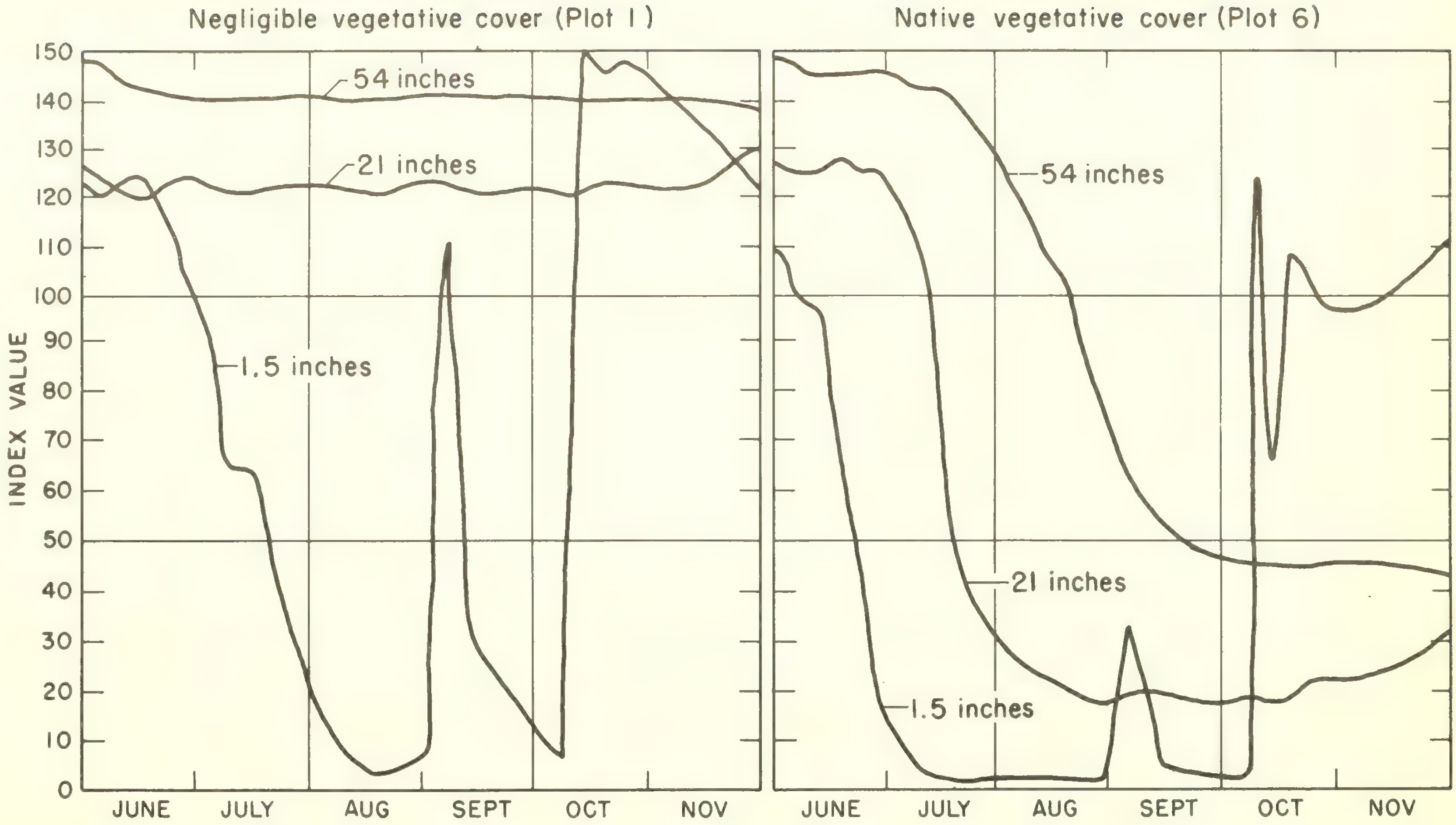

Figure 1.--Trends of soil moisture indices at three soil depths--1.5, 21, and 54 inches--under negligible and native vegetative cover during the first growing season (1953). Indices of 120 to 150 are in the range of high soil moisture; 0 to 30, in the range of low soil moisture.

From the time of bitterbrush seedling emergence until July 13 of the first growing season (table 1), seedling mortality was essentially equal at all competition levels. Soil moisture below 1.5 inches held up well until about this date under both clear-cultivated and undisturbed conditions. Mortality before July 13 can probably be attributed, at least in part, to cutworms and other insects. After that date, the bulk of the die-off was probably due to the lack of soil moisture. It was during the latter period that the big differences in mortality began to show up between the plots with negligible and heavy competition. Considerable mortality occurred during the second year in the undisturbed and crested wheatgrass areas, and the third year in the crested wheatgrass area. Under negligible and light competition few seedlings died in the second year and none in the third.

The most striking contrast, however, was in the size of bitterbrush seedlings under the different levels of competition (table 2, fig. 2). Bitterbrush seedlings under heavy competition grew only during a relatively short time in the spring. Those on the plowed area continued to grow throughout the summer. After three growing seasons seedling heights varied from 4.5 inches on the undisturbed native area, and 5.5 inches on the crested wheatgrass area, to 26 inches on the plowed and weeded plots.

The difference in the vigor of the plants was also reflected in development of their root systems. Under light and negligible competition the roots penetrated to 42 inches during the first growing season and were extensively branched. Under heavy competition they penetrated only 20 to 30 inches and generally were unbranched, thin taproots (fig. 3).

Table 2.--Average height through three growing seasons of bitterbrush seedlings emerging in the spring of 1953 under different levels of competition

Level of competition	End of first growing season	End of second growing season	End of third growing season
	- - - - -	Inches	- - - - -
Negligible	6.0	13.8	26.0
Light:			
Weeded during first growing season	6.0	12.8	21.4
No weeding	4.7	9.5	18.0
Heavy:			
Crested wheat	1.9	2.8	5.5
Native vegetation	1.3	2.6	4.5

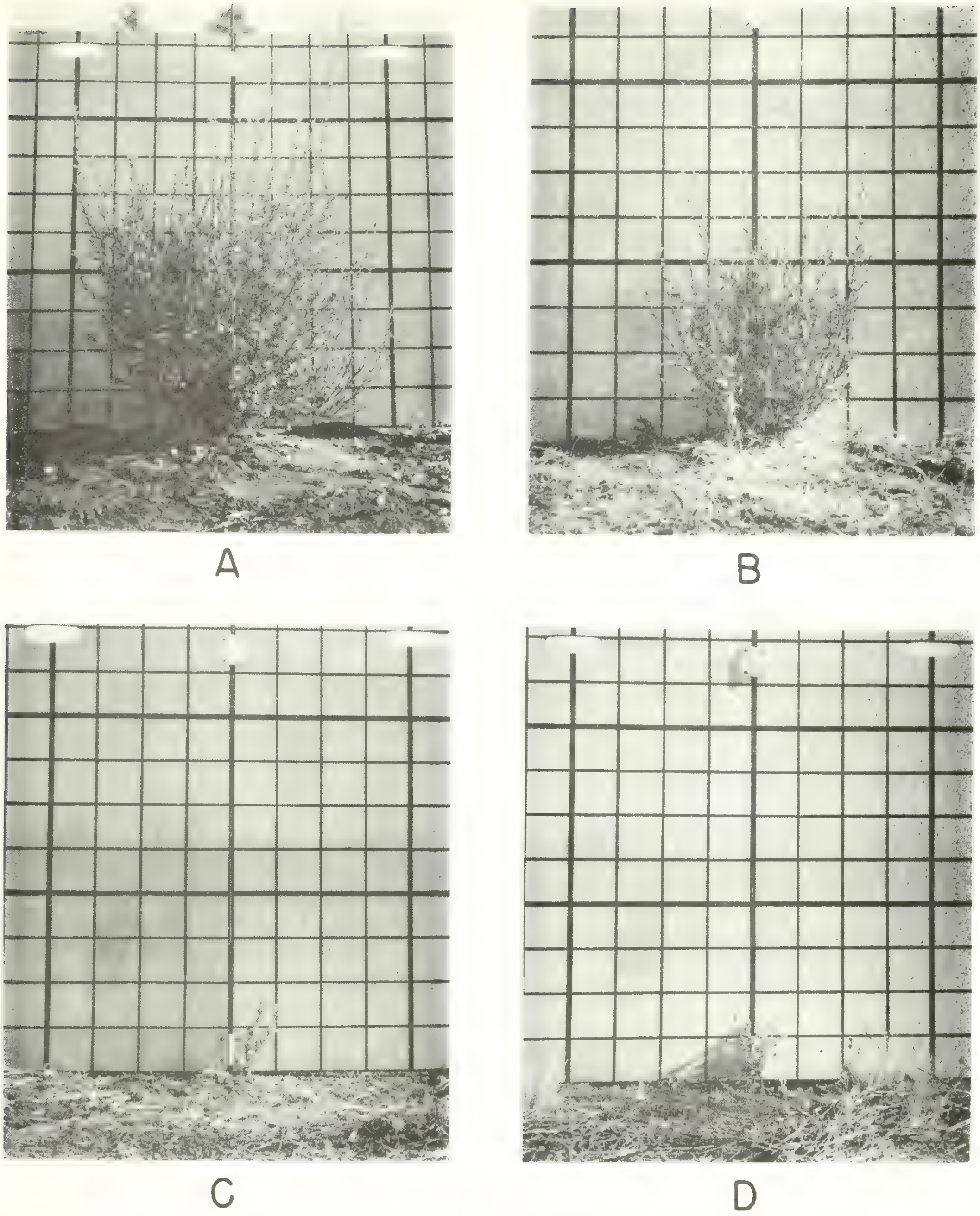

Figure 2.--Three-year-old bitterbrush seedlings under four levels of plant competition at the Flukey Spring experimental area. A. Negligible competition. B. Light competition. C. Heavy competition, crested wheatgrass. D. Heavy competition, native vegetation. (Small squares on backboard are 3 inches across.)

The difference in the vigor of the plants was also reflected in development of their root systems. Under light and negligible competition the roots penetrated to 42 inches during the first growing season and were extensively branched. Under heavy competition they penetrated only 20 to 30 inches and generally were unbranched, thin taproots (fig. 3).

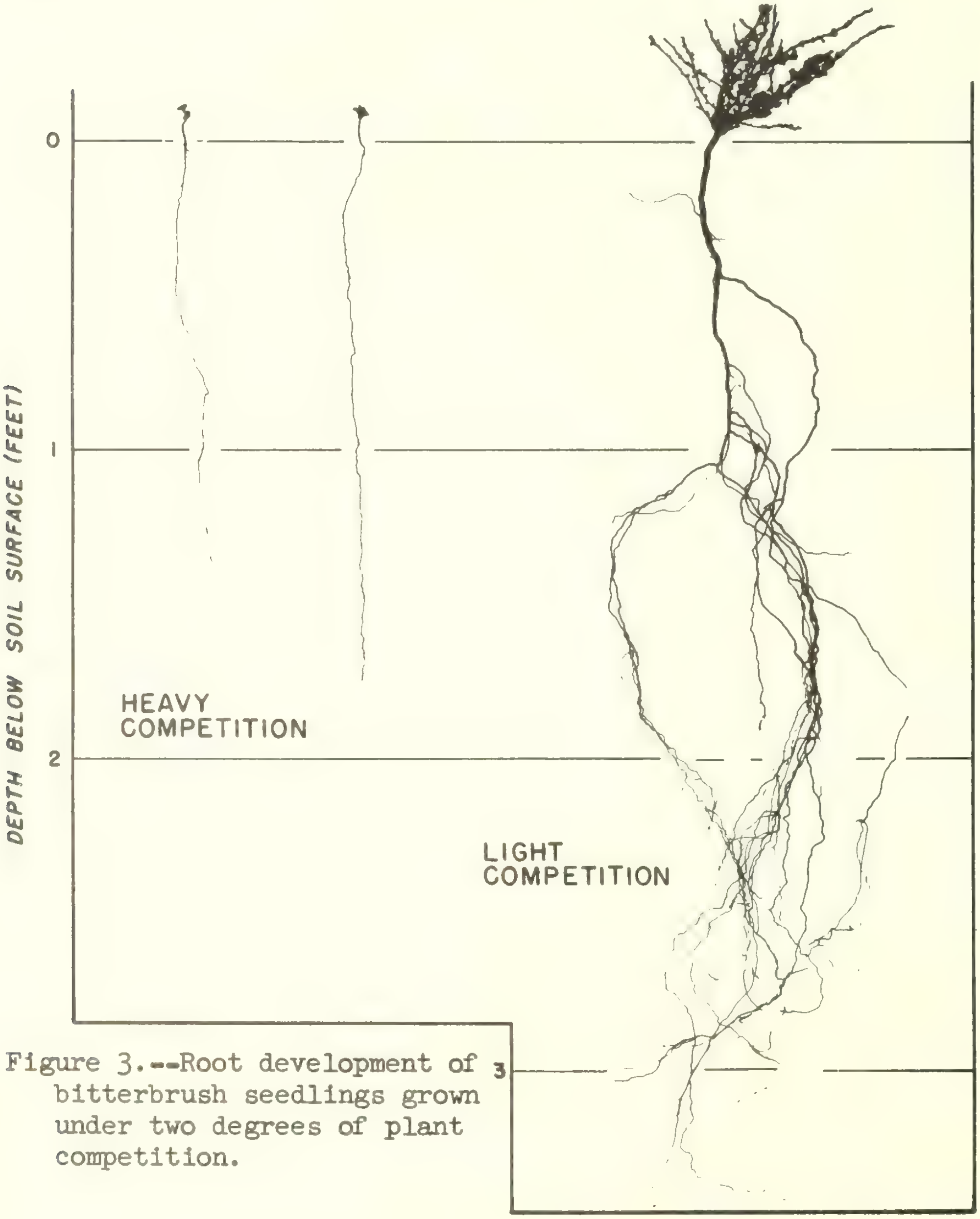

Figure 3.--Root development of bitterbrush seedlings grown under two degrees of plant competition.

Conclusions and Summary

Seedbed preparation, alone and with subsequent weeding, permitted greatly increased seedling growth of bitterbrush and reduced seedling mortality. Even though some of the seedlings growing under heavy competition from native plants may survive many years, there is little chance that they will break free of the competition and become dominant plants. This study was conducted under favorable site and precipitation conditions. Preliminary results from another study indicate that complete mortality of emerged bitterbrush seedlings may occur under less favorable conditions on native, untreated areas.

Weeding after seedbed preparation increased the growth rate of bitterbrush seedlings over soil preparation without follow-up weeding, but the increase was not enough to warrant the extra expense. Weeding could not be justified in an extensive range seeding program.

Planted crested wheatgrass provided about the same level of competition as native vegetation, judging from growth performance of bitterbrush seedlings. It may sometimes be desirable to seed both bitterbrush and crested wheatgrass to provide additional forage, reduce livestock use of bitterbrush, or aid fire protection. Seeding of this type was done (U. S. Forest Service, 1950)3/ in Oregon with the two species sown in alternate drill rows. Seeding alternating drill widths might be another feasible method. Mixing the two species, as in the present study, seems unlikely to give satisfactory results.

Many areas suitable for bitterbrush reseeding would be expensive to cultivate; some would be impossible, but other methods of removing competing vegetation, such as burning and chemical spraying, can sometimes be used. It would be advisable to study other sites and other levels of competition to determine the maximum level of competition by sites under which satisfactory establishment and growth of bitterbrush seedlings can be obtained. Economical methods of reducing existing vegetation must then be developed.

3/ U. S. Forest Service. 1950. Report of bitterbrush seeding on the Paisley Ranger District, Fremont National Forest. 2 pp. (mimeo.)

FOREST RESEARCH NOTES
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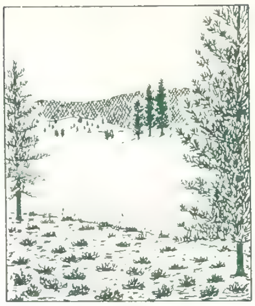

No. 110

August 20, 1956

CALIFORNIA CONE CROP--1956

Gilbert H. Schubert, Forester,
Division of Forest Management Research

Prospects are favorable for a good cone crop of most commercial forest trees in California in 1956. Generally the crop was at least light. Medium crops were twice as frequent as light or heavy ones. Of the major species, incense-cedar was the only one which was reported as having no cones throughout most of its range.

These are the main conclusions from a study of cone-crop reports sent to the California Forest and Range Experiment Station by members of the California Division of Forestry, the California Region of the U. S. Forest Service, and the Southern California Edison Company.

The reports were generally based on occular estimates in which the crop was rated as none, very light, light, medium, or heavy according to the cone crop classification used in Oregon [1]. In this classification the cone crop ratings are:

1. None--no cones on any trees or few cones on occasional trees.

2. Very light--few cones on 25 percent of the trees, or few cones on 25 percent of the trees and many cones on occasional trees.

3. Light--few cones on 75 percent of the trees, or many cones on some trees and few cones on 75 percent of the trees.

4. Medium--some cones on all trees, or many cones on less than 75 percent of the trees.

5. Heavy--many cones on 75 percent of the trees and some cones on all trees, or many cones on all trees.

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[1] Engstrom, W. H. Oregon cone crop, 1954. Oregon State Board of Forestry. Res. Note 16, 7 pp., 1954.

Although these ratings are subjective, they provide valuable information for those planning to collect seed this fall.

As an aid to seed collectors, the crop reports have been segregated according to the forest tree seed collection zones described by Fowells [2]. This grouping (table 1), showed that the most promising localities for collecting seed of major commercial conifers--those with medium to heavy or heavy cone crops--were as follows:

	Collection Zone
Douglas-fir - - - - - - - - -	X, XI, XII
Red fir - - - - - - - - -	VI
White fir - - - - - - - - -	VI, VII
Jeffrey pine - - - - - - - -	IV, VI, X
Ponderosa pine - - - - - - -	IV, X, XI
Sugar pine - - - - - - - - -	II, III, IV, VII, XI

A map of the collection zones is appended to this note, but since the seed crop varies widely in most zones, it is also advisable to consult field officers of the California Division of Forestry or the U. S. Forest Service.

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[2] Fowells, H. A. Forest tree seed collection zones in California. Calif. Forest and Range Expt. Sta. Res. Note 51, 5 pp., illus. 1946.

Table 1.--Summary of cone crops by species and seed zone, California, 1956

Species	County or Seed Collection Zone	Cone Crop [1]
CEDAR:		
Incense-cedar (*Libocedrus decurrens*)	I, IV, V, IX, X	None to light
	II, III, VII, VIII	None
DOUGLAS-FIR:		
Bigcone Douglas-fir (*Pseudotsuga macrocarpa*)	IX	None to very light
Douglas-fir (*P. menziesii*)	I	Very light to heavy
	II, III	Light to heavy
	IV, V	Medium
	X, XI, XII	Medium to heavy
	XIII	Light to medium
FIR:		
Lowland white fir (*Abies grandis*)	XI, XII	Light
	XIII	Medium
Red fir (*A. magnifica*)	I	Very light to medium
	II	Light
	III	Light to medium
	V	Very light to medium
	VI	Heavy
	VII	Very light to heavy
	VIII	Very light to medium
	X	Very light
White fir (*A. concolor*)	I	Very light to heavy
	II	None to heavy
	III	Light to heavy
	IV, V	Very light to heavy
	VI	Heavy
	VII	Medium to heavy
	VIII	Very light to heavy
	IX	Very light to medium
	X	Light to heavy
PINE:		
Bishop pine (*Pinus muricata*)	XII	Light
	XIII	Medium
	Monterey	Very light
Coulter pine (*P. coulteri*)	IX	Very light to medium
	Fresno (Westside)	Very light
	San Benito	Very light

Species	County or Seed Collection Zone	Cone Crop[1]
PINE: (continued)		
Jeffrey pine (*P. jeffreyi*)	I	None to heavy
	II	Very light to medium
	III	Very light to heavy
	IV	Heavy
	V	Very light to heavy
	VI	Heavy
	VII	Very light to light
	VIII	None to medium
	IX	Very light to medium
	X	Medium to heavy
	Kern (Tehachapi area)	Light
Lodgepole pine (*P. contorta*)	XII	Light
	XIII	Medium to heavy
Monterey pine (*P. radiata*)	XIII	Light
Ponderosa pine (*P. ponderosa*)	I	Very light to heavy
	II, III	Light to heavy
	IV	Medium to heavy
	V	Light to heavy
	IX	Very light to medium
	X, XI	Medium to heavy
	XIII	None
Sugar pine (*P. lambertiana*)	I	Light to heavy
	II, III, IV	Medium to heavy
	V	Light to heavy
	VII	Medium to heavy
	VIII	Very light
	IX	Light to medium
	X	Light to heavy
	XI	Medium to heavy
	XIII	Medium
Torrey pine (*P. torreyana*)	IX	None
SEQUOIA:		
Giant sequoia (*Sequoia gigantea*)	IV	None to very light
	V	Light
Redwood (*S. sempervirens*)	XII	Medium
	XIII	Very light to medium

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[1] Reported by technicians of the California Division of Forestry, the California Region of the U. S. Forest Service, and the Southern California Edison Company.

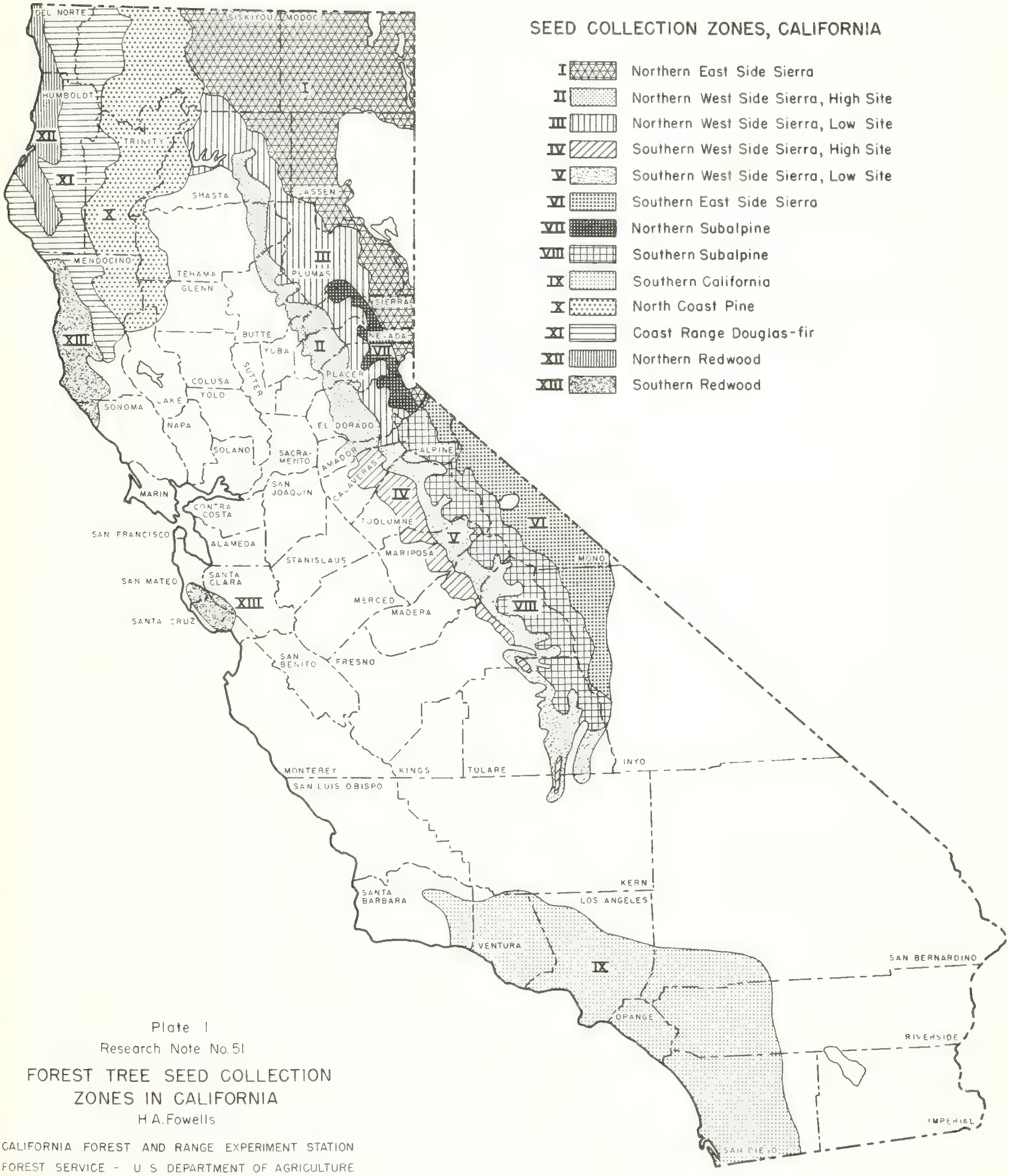

Plate I

Research Note No. 51

FOREST TREE SEED COLLECTION ZONES IN CALIFORNIA

H. A. Fowells

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U S DEPARTMENT OF AGRICULTURE

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 111

August 31, 1956

RANGE SPECIES RECOMMENDED FOR SOWING ON CLEARED BRUSHLAND IN CALIFORNIA[1]

J. R. Bentley, Range Conservationist, California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; Lester J. Berry, Agriculturalist, Agricultural Extension Service, University of California; Donald R. Cornelius, Range Conservationist, Agricultural Research Service, U.S. Department of Agriculture; and R. Merton Love, Professor of Agronomy, Department of Agronomy, University of California.

The choice of forage plant mixtures to sow on an area cleared of brush is limited by seedbed and site conditions. Where a variety of species can be successfully established, the choice may depend on the kind of cover that is desired. Mixtures adapted to different conditions and objectives are of two general kinds: Those dominated by annual grasses and those dominated by long-lived perennial grasses.

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[1] Species are recommended for the chaparral and woodland types in the brushland zone below the commercial timber belt. Excluded are the sagebrush and associated types east of the Sierra-Cascade and the desert shrub types.

The recommendations express the joint conclusions of the four authors representing their respective departments or agencies in the University of California and the United States Department of Agriculture. The authors are indebted to other members of the Extension Service and Forest Service for field tests of species performance and for review of the recommendations and suggestions on preparation of this paper. The recommendations are based on observations of reseeding results extending over a period of nearly 20 years. The recommended basic mixtures are intended for use statewide within the brush zone, but alternate species are suggested for use at the discretion of men with local experience in reseeding.

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Mixtures Dominated by Annuals

Annual grasses are recommended for areas where good stands of perennials cannot be established because of poor sites or unsuitable seedbeds. Annuals are the better choice on most rocky soils about 1 foot deep and on some deeper soils that are coarse textured and excessively drained. Annuals usually are recommended for an area if only small spots have a weed-free seedbed suitable for perennials. Annuals also can be used on burned watersheds where the major objective is a full cover the first 2 years after sowing and range improvement is secondary. On cleared ranges or watersheds recommended for annuals, however, perennials can well be sown on selected areas of suitable site and seedbed.

Annuals should be sown at a rate sufficient to obtain a continuous cover the first year. A full initial stand will take advantage of any temporary increase in soil fertility resulting from brush removal. Sowing of annuals is not worthwhile unless they provide a quick cover and good grazing before a stand of resident annuals becomes established naturally.

Basic Annual Mixture

A basic mixture widely adapted for broadcast sowing in the brushland zone is:

Species:	Pounds per acre
Soft chess	5
Annual legumes	5
	10

Soft chess, a desirable grass widely naturalized in the foothills, has consistently produced good stands from broadcast sowing. It grows well under good conditions and, perhaps more important, is the only commercial species adapted to hard seedbeds and low soil fertility. A distinct advantage of soft chess for range improvement is that it provides only limited competition with other sown species and persists in the grass cover.

Soft chess is commercially available as Blando brome. Seed supplies are limited and the price is relatively high. For these reasons part or most of the soft chess in the basic mixture may have to be replaced by other annual grasses.

Annual legumes should make up about half of an annual-plant mixture wherever improvement of grazing values is desired. Rose clover, subterranean clover, crimson clover, and burclover should be included. Conditions favorable for each species usually occur somewhere within an area to be sown, and a mixture of species gives more consistent production under variable weather conditions.

The grass seed should have a recommended fungicidal treatment and the legume should be inoculated at a heavy rate.

Alternate Species

When soft chess is not available or is too costly, annual ryegrass can replace most of the soft chess in the mixture on many areas. Good mellow seedbeds are needed for broadcast sowing of ryegrass. The seed should be covered mechanically on hard seedbeds or where average precipitation is less than about 20 inches. Soil fertility should be at least fair. Good stands of ryegrass are valuable because of their high production for a few years and their heavy first-year competition with brush seedlings. Ryegrass has two major limitations, however: Excessive competition with other sown forage species and limited persistence in the grass cover. Typically, ryegrass is dominant for only 2 to 4 years and often is replaced by inferior species. On some fertile soils, particularly in the coastal region, ryegrass will become naturalized and persist indefinitely. On such sites it is a first-choice annual grass.

Seed of annual ryegrass is available in quantity at a low price. Sowing at 5 pounds per acre is recommended for a uniform stand. Higher rates are not necessary. Two to 3 pounds will produce good stands in favorable years. Soft chess always should be added at one-half to 2 pounds per acre with the ryegrass. Then soft chess will become established before ryegrass disappears from the cover.

A few short-lived perennial grasses may be included, but the mixture will remain essentially annual in nature. Perennial ryegrass is interchangeable with annual ryegrass on fertile soils where precipitation is greater than about 25 inches per year. Where mountain brome, Harlan brome, or prairie brome have shown exceptional promise they can be added to the basic mixture at about 2 pounds per acre. If ryegrass is the dominant annual in a mixture with perennial bromes, it should be reduced to 2 pounds per acre.

Soft chess sown on area of chamise-chaparral burned for game range improvement. This is best adapted species for broadcast sowing on shallow rocky soils with hard seedbed surface. Mendocino National Forest, Lake County, 1953.

Seedbed favorable for sowing perennials on selected area of productive soil with moderate gradient. Wildfire burn in mature mixed-chaparral has left mellow soil surface with few viable weed seeds. Santa Barbara County, 1955.

Excellent stand of Hardinggrass on productive land where brush was removed by burning. This palatable perennial, which will persist indefinitely if properly grazed, is the basic species for most perennial mixtures. Rescue Range, El Dorado County, 1955.

Perennial grass cover on selected site on chamise-chaparral watershed burned by wildfire. Tall fescue and intermediate wheatgrass replace part of Hardinggrass in the basic mixture. Brush sprouts and seedlings killed by chemical spraying. Mendocino National Forest, Glenn County, 1955.

Veldtgrass, a vigorous reseeding perennial, can be added to the annual grass mixture at 2 pounds per acre in coastal areas, or inland in southern California, on light-textured soils.

Sowing of wild oat is a questionable practice that adds to the difficulty and cost of sowing and appears to give limited return.

Cereal grains, particularly rye, often will provide good temporary cover when sown on good seedbeds at 40-50 pounds per acre. These rates are too high for economical application by aircraft. Soft chess or ryegrass can be used more economically and will give better success on most seedbeds.

Mixtures Dominated by Perennials

Perennial grasses can be used to improve forage values of the herbaceous cover over much of the brush zone--but only if grazing is managed to promote their establishment and continued production. If the decision is to sow perennials, provision for the necessary grazing control should be planned before the area is sown. Perennials may be sown on relatively small areas that can be fenced out as separate units. Or the entire range may be managed so that perennials can be grown wherever soil conditions are favorable. Perennials should not be grazed yearlong, and a rest period during seed production is needed at least once in 3 years.

Perennial grasses are recommended for sowing where adapted because they are superior to annuals. They are deeper rooted and have a more stable production of usable herbage over a longer period of the year. The extent to which the increased costs and greater care necessary to establish and maintain perennials may be economically justified has not been determined for many conditions on livestock, game, or dual-use ranges. However, worthwhile improvement of the cover for grazing or soil protection is obvious on many areas where perennials have been successfully established.

A successful burn in dense brush will provide the relatively weed-free seedbed required for a full stand of perennials. Areas cleared by bulldozing or disking are sufficiently weed-free if few annuals were present before clearing, or if annuals were reduced by thorough cultivation in the spring before they produced seed. A burn in open or semidense stands of brush usually is poor for sowing of perennials unless the competing plants have been reduced by cultivation, or sowing is confined to the small spots of clean seedbed.

Perennial grasses can be successfully grown inland where precipitation averages about 25 inches or more and soils about 2 feet deep or deeper, except on coarse-textured soils that are excessively drained. If precipitation averages less than 25 inches, the soil should be deeper than 2 feet. Texture should be loam to clay loam or the subsoil should be heavy clay.

Perennials will succeed in coastal areas under precipitation considerably less than that required inland.

Where mixtures dominated by perennials are to be sown, the objective should be to obtain a full stand of the long-lived species during the first year, when competition is at a minimum. Therefore, heavy seeding rates are recommended.

Basic Perennial Mixture

A basic mixture recommended for broadcast sowing in the brushland zone is

Species:	Pounds per acre
Hardinggrass	5
Smilo	2
Soft chess	1/2 - 2
Legumes	4
	11 1/2 - 13

If the mixture is drilled the total rate per acre can be reduced to about 50 percent of the broadcast rate, but the species proportions should be the same. Drilling is recommended for best establishment of perennials although good stands often have been obtained by broadcast sowing, usually aerial application, on burned brushland.

Hardinggrass should be the major species in perennial grass mixtures over most of the brushland zone. Where adapted it is the most productive, under grazing and reburning, of the long-lived species that are commercially available.

Above elevations of about 3,000 feet at the north end of the brushland zone and above 5,000 feet at the south, winters are too cold and long for best production of Hardinggrass. Here, some other species can be used as the major one in a perennial grass mixture.

Because seed of Hardinggrass is in short supply, other species may need to be substituted for part of the Hardinggrass on many areas, but at least 3 pounds of Hardinggrass seed per acre should be included where it is broadcast sown.

Smilo is another long-lived species recommended for the basic mixture of soils where Hardinggrass is adapted, and smilo will survive on shallower soils underlain by highly fractured substratum. Smilo is particularly suited for broadcast sowing on areas of burned chamise-chaparral. The rate may be increased to replace part of the Hardinggrass in the basic mixture where precipitation averages less than 20 inches. Seed supplies are adequate and the price is reasonable.

Soft chess is recommended for the basic mixture to fill in the interspaces between perennials during the second and third years after sowing. Sown at 1/2 to 2 pounds per acre, it will produce an adequate amount of well distributed seed but will not compete excessively with perennial grass seedlings.

The mixture should include several annual legumes to increase production and grazing values. Those recommended are rose clover, subterranean clover, crimson clover, and burclover. Alfalfa may be used as one of the legumes without danger of excessive competition. Ordinarily it produces satisfactory stands when sown on deep soils of neutral or slightly alkaline reaction but adds little to total herbage production. Alfalfa stands often are decimated by rodents.

All grass seed should have recommended fungicidal treatment and the legume seed should be inoculated at a heavy rate.

Alternate Species

Orchardgrass and Tualatin tall oatgrass are best adapted at the north end of the brushland zone and in the North Coast Ranges where annual precipitation is greater than 30 inches. Here, either species can replace part of the Hardinggrass in the basic mixture on the best sites. On other sites, adding about one-fourth pound of orchardgrass per acre to the basic mixture will provide many new seedlings the second year after sowing. At higher rates orchardgrass competes excessively with Hardinggrass and smilo the first year. At elevations too high for best growth of Hardinggrass in northern and central California, orchardgrass or Tualatin tall oatgrass may replace it as the major species in the mixture. Fresh seed of tall oatgrass should be used because germination of this species falls off rapidly as the seed ages.

Tall fescue or intermediate wheatgrass, or both, may be used within the brushland zone in northern and central California where annual precipitation averages more than 25 inches, to replace about 2 pounds of Hardinggrass in the basic mixture. These species, too, can be used as the major species at elevations too high for best growth of Hardinggrass.

Big bluegrass is widely adapted in northern and central California. It may be added to the basic mixture or used to replace part of the annual grass in the mixture.

Veldtgrass is best adapted in southern and coastal California, where it grows well on light-textured soils. On such sites it is recommended to replace part of the Hardinggrass in the basic mixture.

Intermediate wheatgrass probably is more productive on cleared brushland north of the Sacramento Valley, but three other wheatgrasses--pubescent, tall, and crested--also are adapted in this region. These wheatgrasses are recommended for sowing on a trial basis in southern California at elevations too high for Hardinggrass, particularly on the desert side of the mountains.

Highland bent, creeping red fescue, Chewings fescue, and hard fescue are recommended for trial sowings at elevations too high for Hardinggrass. They should be tested where a good ground cover is needed on soils with neutral to acid reaction in areas of good precipitation.

Birdsfoot trefoil is a perennial legume that may be added if desired. It has about the same soil requirements as alfalfa but has not been so widely successful. Burnet is a non-leguminous perennial that usually produces fair to good stands on favorable sites when sown at 1 or 2 pounds per acre, and it persists for many years on some areas. It usually adds little to the forage available to livestock, partly because of heavy deer grazing on this species. Burnet should have more trial on deer ranges.

If annual or perennial ryegrass is used instead of soft chess, it should not be sown at a rate greater than one-half pound per acre because ryegrass is extremely competitive. One of the short-lived perennial bromes may be added at a low rate along with an annual grass in the mixture.

COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Alfalfa	Medicago sativa
Bent, Highland	Agrostis tenuis
Bluegrass, big	Poa ampla
Brome, Blando	Bromus mollis
Brome, Harlan	Bromus stamineus
Brome, mountain	Bromus marginatus
Brome, prairie	Bromus catharticus
Burclover	Medicago hispida
Burnet	Sanguisorba minor
Clover, crimson	Trifolium incarnatum
Clover, subterranean	Trifolium subterraneum
Clover, rose	Trifolium hirtum
Fescue, Chewings	Festuca rubra var. commutata
Fescue, creeping red	Festuca rubra
Fescue, hard	Festuca ovina var. duriuscula
Fescue, tall	Festuca arundinacea
Hardinggrass	Phalaris tuberosa var. stenoptera
Oatgrass, Tualatin tall	Arrhenatherum elatius
Orchardgrass	Dactylis glomerata
Rye	Secale cereale
Ryegrass, annual	Lolium multiflorum
Ryegrass, perennial	Lolium perenne
Smilo	Oryzopsis miliacea
Soft chess	Bromus mollis
Trefoil, birdsfoot	Lotus corniculatus
Veldtgrass	Ehrharta calycina
Wheatgrass, crested	Agropyron desertorum
Wheatgrass, intermediate	Agropyron intermedium
Wheatgrass, pubescent	Agropyron trichophorum
Wheatgrass, tall	Agropyron elongatum
Wild oat	Avena fatua

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 115 September 28, 1956

PRUNING PONDEROSA AND JEFFREY PINE

William E. Hallin, Forester
Division of Forest Management Research

Ponderosa and Jeffrey pine shed their limbs very slowly. Consequently they must be pruned if clear lumber or veneer is desired in second-growth timber that is grown in rotations of 140 years or less. The pruning ought to be done at an early age to produce as much clear wood as possible. Furthermore, in open stands the lower limbs of these pines grow rapidly in diameter. If delayed, pruning may become too costly because of the large branches resulting from rapid growth.

Pruning also ought to extend as high as possible to increase the yield of clear wood. An important question, then, is: how much of the live crown can be removed without seriously reducing the tree's growth rate? Studies in other regions have indicated that removing one-fourth has little effect on growth rate, and pruning half the crown often does not have a serious effect. Experimental pruning in California has shown that half the live crown can safely be removed if four-tenths of the tree height remains in green crown after pruning.

The Study

The study was started at Blacks Mountain Experimental Forest in 1947. Twenty-five groups of four ponderosa or Jeffrey pine crop trees were selected in an open-grown stand. Treatments consisted of no pruning and removal of one-fourth, one-half, and three-fourths of the green crowns, assigned at random to the four crop trees in each group. The diameters of the trees were recorded when the study was started and 2 years and 5 years later. The 100 trees selected for the experiment ranged from 2.8 to 8.8 inches in diameter and averaged 5.4 inches. Study trees were selected at the rate of about 20 per acre in stands with densities of 40 to 50 per acre. The average site index at Blacks Mountain is 72. 1/

1/ Meyer, Walter H. Yield of even-aged stands of ponderosa pine. U. S. Dept. Agr. Tech. Bul. 630. 59 pp., illus. 1938.

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Results

For the first 5 years after pruning, removal of one-fourth of the crown had no effect on diameter growth (table 1). Removal of half the crown reduced the growth rates by about 23 percent. Thirteen trees, or 52 percent, of those with three-fourths of the crown removed died. All of the trees that died had been attacked by the red turpentine beetle (Dendroctonus valens Lec.). Five other trees with three-fourths of the crown removed, two with one-fourth of the crown removed, and one with no pruning survived attacks of this beetle.

Table 1.--Diameter growth after pruning ponderosa and Jeffrey pine, Blacks Mountain Experimental Forest

Amount of live crown removed	Annual growth		Five years growth	Basis, trees
	First 2 years	3 to 5 years		
	- - - Inches	- - -	Inches	Number
None	0.36	0.30	1.63	25
1/4	0.35	0.32	1.68	25
1/2	0.22	0.27	1.27	25
[1] 3/4	0.06	0.12	0.49	12

[1] Only trees alive at the end of 5 years included.

Perhaps the most striking thing shown by this study is the rapid diameter growth rate of open-grown young trees. All of the trees with none or one-fourth of the crown removed grew 1.0 inch or more in 5 years; 90 percent of them grew 1.3 inches or more in 5 years. The maximum growth was 2.6 inches for 5 years. All of the trees with half of the crown removed grew 0.8 inch or more in 5 years, and 92 percent grew 1.0 inch or more.

Although growth was reduced by removing half of the crown, it still was adequate for practical purposes. For one thing, annual growth increased during the first 5 years. If this trend continues, the trees with half their crowns removed can be expected to be growing as fast as those with only one-fourth removed before the end of the second 5-year period. Then too, higher pruning could mean that an extra 4-foot length of bole can be pruned. Then the total amount of clear wood produced should be greater even though the growth rate is temporarily reduced.

Length of live crown averaged 0.86 of the total height of the trees. Eighty-four percent of the trees had crowns longer than 0.80 of the total height. On the average, trees with one-fourth of the crown removed had a remaining crown length of 0.64; those with half of the crown removed, 0.43; and those with three-fourths of the crown removed, 0.22 of the total height of the trees.

Thus it would be appropriate to remove as much as half of the green crown in pruning, provided that at least four-tenths of the total height of the tree retained live crown after pruning.

Supporting Evidence

In another thinning study half of the crop trees were pruned and half were not on plots in moderately to fully stocked pole stands. The average d.b.h. of the crop trees was 7.6 inches, and their average crown length was 0.62 of the total tree height. Not more than a third of the green crown was removed from any tree, the average being about one-fourth.

The average crown length after pruning was 0.53 of the total tree height. Growth was practically the same on pruned and unpruned trees, being only 0.03 inch less per pruned tree for a 5-year period. Consequently, by inference, removal of half of the green crown can be recommended for all ponderosa and Jeffrey pine if at least four-tenths of the total height remains in green crown after pruning.

Application

As a practical guide to pruning, curves were prepared for total height of crop trees by diameter to show the height to which trees of different d.b.h. could be pruned (table 2). A pruning height of 0.6 of total height was assumed. On the average, open-grown crop trees must be 8 inches in diameter before 10 feet of bole can be cleared and 14 inches in diameter before a height of 18.5 feet can be pruned. In contrast, closely grown 4-inch diameter trees can be pruned to 10 feet and 9-inch trees can be pruned to 18.5 feet. Consequently, in the typical eastside pine of northeastern California pruning must be done in two or more stages if the knotty central core is to be kept small.

Table 2.--Total height and maximum pruning height, by d.b.h. [1]

D.b.h., inches	Crop trees in open stands		Crop trees in closed stands	
	Total height	Pruning [2] height	Total height	Pruning [2] height
	Feet	Feet	Feet	Feet
4	12.0	7.2	16.5	9.9
6	15.5	9.3	22.5	13.5
8	19.5	12.7	28.5	17.1
10	23.0	13.8	34.5	20.7
12	27.0	16.2	40.5	24.3
14	31.0	18.6	46.5	27.9

[1] Site index 70. See footnote 1, p. 1.

[2] Pruning height when four-tenths of total height is left with green crown. Pruning to height greater than 18.5 feet is not recommended.

In general, trees should be pruned when they are as small as possible to permit the growth of the widest possible ring of clear wood. Sometimes, however, pruning of trees as large as 14 inches in diameter can be justified. For example, a fairly large knotty core is less objectionable in a veneer bolt than in a sawlog. Also, it is better to prune a vigorous, dominant 14-inch tree than a slower growing neighbor of smaller diameter. In establishing maximum size of trees to be pruned, expected growth rate, necessary minimum radius of clear wood and planned time of harvesting all must be considered.

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 116

October 15, 1956

EFFECT OF FERTILIZER ON CONE PRODUCTION OF SUGAR PINE

By Gilbert H. Schubert, Forester,
Division of Forest Management Research

Fertilizing seed trees may be one way to improve reforestation of cut-over and fire-destroyed timber stands in California. One of the chief difficulties in reforestation here is that most of the commercial conifers do not produce good crops of seed-bearing cones often enough. Heavy crops have been as much as 7 years apart. As a result an adequate supply of seed for natural regeneration seldom occurs at the right time on cut-over areas. If artificial regeneration is relied on for new timber crops, tree planters have to collect and store large quantities of seed during the few good years to tide them over the many poor ones. Heavier crops at shorter intervals would help solve a good many of these problems. That this objective may be reached through fertilization is shown by a preliminary test the Experiment Station recently completed with applications of ammonium phosphate around sugar pines.

The Study

In the spring of 1951, 8 pairs of dominant sugar pines ranging from 27 to 52 inches in diameter (table 1) were selected. Half were treated with 100 pounds of ammonium phosphate (16-20-0) per tree. The fertilizer was spread on the ground beneath each tree over an area equivalent to the crown spread. The treatments were repeated in the spring of 1952 and 1953.

The trees selected for this study were on a part of the Stanislaus Experimental Forest which had been logged in 1948. All seed trees selected had been released and though all trees were not released to the same degree, the differences were considered too small to bias this exploratory study.

Results

Since sugar pine cones require 2 years to mature, no effect of the fertilizer was expected until 1953. None of the trees bore cones in 1951. In 1952, 4 of the fertilized trees bore more cones than their unfertilized counterparts and 4 had less cones. Of the 2,073 cones

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produced on the fertilized trees, 848 cones were borne on one tree (fig. 1, table 2). The average for the 7 remaining fertilized trees was 175 cones, compared to 181 for the 8 untreated trees. Thus, the fertilized and unfertilized seed trees were similar in cone-producing capacity.

During the 4-year period, 1953-6, when the fertilizer may have had an effect on cone production, the fertilized trees produced nearly three times as many cones as the unfertilized trees. Seven of the eight fertilized trees bore more cones than their unfertilized controls.

Although the study indicated that fertilization with ammonium phosphate will increase sugar pine cone production, further study will be required before general recommendations can be made.

Table 1.--Diameter and Dunning tree class of sugar pine seed trees, Stanislaus Experimental Forest, 1951

Treatment and tree number	D.b.h.	Dunning tree class
	Inches	
Fertilized:		
1	48.5	5
2	30.3	1
3	32.8	1
4	39.2	1
5	40.2	1
6	45.8	3
7	52.3	5
8	27.0	1
Unfertilized:		
1	48.8	5
2	27.9	1
3	33.4	1
4	38.4	1
5	38.8	1
6	50.3	3
7	52.0	5
8	26.7	1

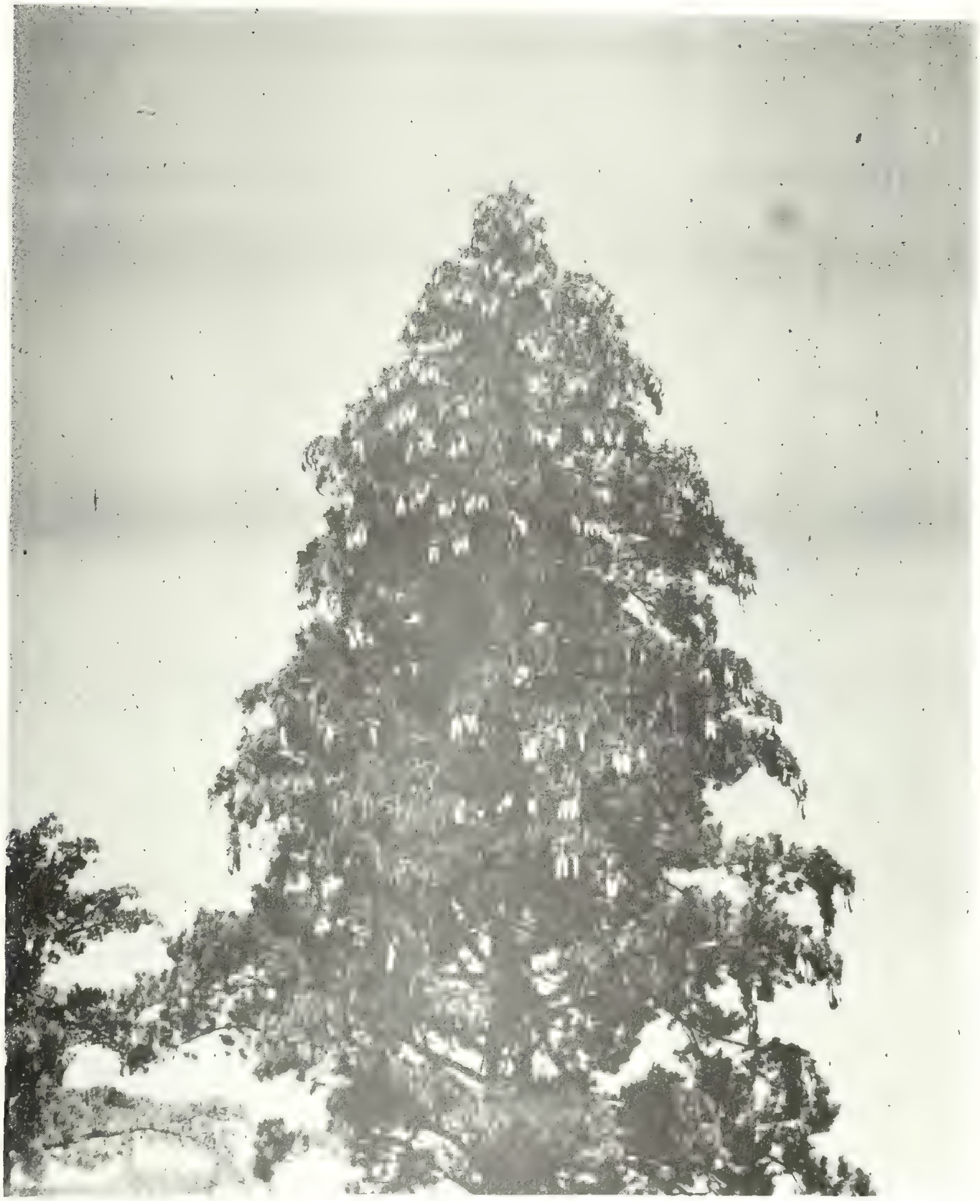

Figure 1.--A 48-inch d.b.h. sugar pine bearing an estimated 848 cones in 1952 on the Stanislaus Experimental Forest. (Fertilized tree No. 1).

Table 2.--Cones produced on fertilized and unfertilized sugar pine seed trees, Stanislaus Experimental Forest, 1951-1956

Treatment and tree number	1951	1952	1953	1954	1955	1956	Total 1953-6
				Number			
Fertilized:							
1	0	848	13	48	131	762	954
2	0	104	10	89	2	64	165
3	0	12	53	74	0	4	131
4	0	156	3	128	1	8	140
5	0	158	0	122	2	154	278
6	0	398	17	145	26	52	240
7	0	321	4	313	0	340	657
8	0	76	0	64	0	69	133
Total	0	2,073	100	983	162	1,453	2,698
Unfertilized:							
1	0	309	3	9	0	70	82
2	0	72	2	23	0	14	39
3	0	152	3	34	0	14	51
4	0	160	10	46	0	165	221
5	0	185	3	182	1	73	259
6	0	9	26	2	0	5	33
7	0	273	3	26	0	161	190
8	0	106	4	15	0	10	29
Total	0	1,266	54	337	1	512	904

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 117 November 21, 1956

EARLY SURVIVAL AND GROWTH OF SUGAR PINE AND WHITE FIR IN CLEAR-CUT OPENINGS

Gilbert H. Schubert, Forester,
Division of Forest Management Research

The preponderance of white fir regeneration on sugar pine management units has always plagued forest managers in the sugar pine-fir type in the Sierra Nevada (fig. 1). Clear cutting small even-aged groups appears to offer at least a partial solution to this problem. In one recent study more white fir than sugar pine seedlings in openings died within 2 years, and more white firs were damaged by freezing and browsing. As a result sugar pine has a head start in the race for dominance.

The Study

The study area is part of the pilot-plant test of unit area control in sugar pine management on the Stanislaus Experimental Forest. During the summer of 1948 several overmature groups of mixed sugar pines and white firs were clear cut. Brush and the small white firs present on the areas were eradicated by a bulldozer while it piled slash. The clear-cut areas and surrounding buffer strips were treated with a lethal bait to reduce the rodent population. Seedtraps and permanent milacre quadrats were used to determine seed effectiveness. The seedtraps, evenly spaced at 1-chain intervals, were placed throughout the clear-cut areas. The permanent quadrats were in lines across the openings.

Results

During the autumn the regeneration areas received an abundant natural fall of sugar pine and fir seeds. An average of 29,000 sugar pine and 160,000 white fir seeds per acre was distributed throughout the clear-cut blocks.

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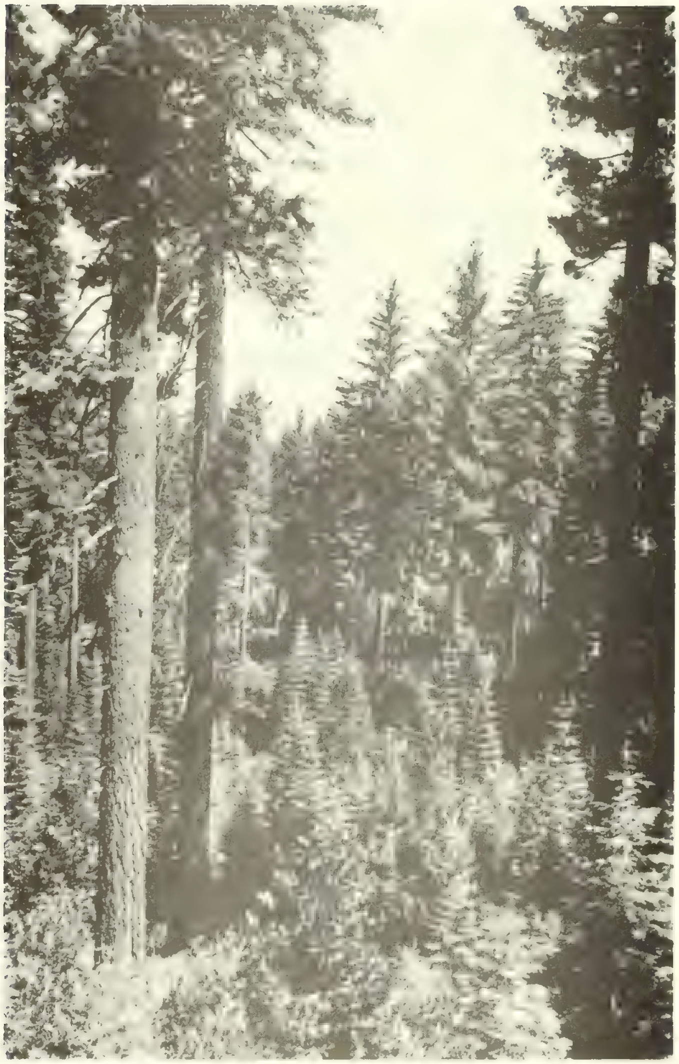

Figure 1.--White fir understory in the sugar pine-fir type in the Sierra Nevada.

At the time of the first reproduction survey in June 1949, the areas averaged 733 sugar pine and 14,298 white fir seedlings per acre. By fall of the same year the per acre stocking was reduced to 509 sugar pines and 7,235 white firs. At the end of the second growing season, there were 401 sugar pines and 3,798 white firs per acre. The total mortality for the 2-year period was 45 percent for sugar pine and 73 percent for white fir.

Although most of the new seedlings were sugar pines and white firs, some ponderosa and Jeffrey pine seedlings came in. Including these scattered trees, the original stocking of all pines was 803 and the final stocking at the end of 2 years was 458 per acre. Although the proportion of the pines in the new stand has only increased from 5 percent to 11 percent of the total stocking, the pines are by far the tallest trees (figs. 2 and 3).

White firs made the least height growth in the 8 years from 1949 to 1956, and Jeffrey pines made the most. Sugar pines were intermediate between white firs and Jeffrey pines, as shown in the following tabulation:

Species	Range in height (Feet)	Average height (Feet)	Basis (Number)
Sugar pine	0.7 - 6.1	2.9	100
Jeffrey pine	1.8 - 8.2	4.3	40
White fir	0.2 - 2.3	0.6	100

Young sugar pines normally grow faster than white firs of the same age, but the large difference in average height is not due entirely to inherent growth characteristics. Late spring freezes during 5 of the 8 years damaged white firs more than the sugar pines. In June 1954, when the temperature dropped below 20° F., most of the new growth on the terminals and laterals of the white firs was completely destroyed. The only white firs which sustained little or no damage were those sheltered by brush or pines. Although there were too few red firs in the clear-cut openings for conclusive comparisons of frost resistance, red fir appeared to be intermediate between white fir and sugar pine (fig. 3). None of the ponderosa or Jeffrey pines were injured by any of the late spring freezes.

Browsing damage by deer was also observed throughout the regeneration areas. As with freezing injury, white firs were hit hardest, whereas the pines were seldom molested.

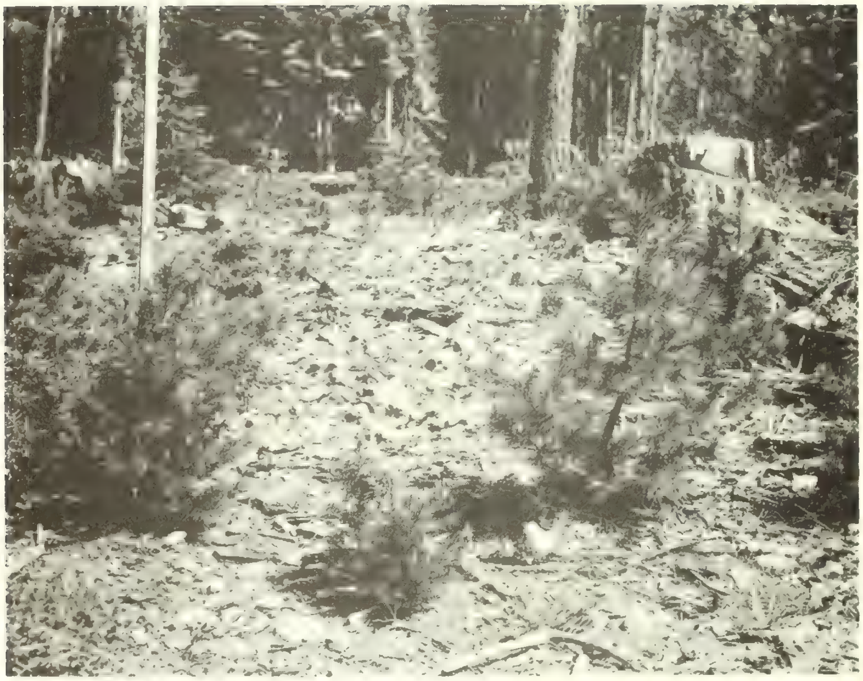

Figure 2.--Seven-year-old sugar pine and white fir seedlings, Stanislaus Experimental Forest, August 1955. The small plant in the center foreground is a white fir. It is flanked on each side by a much taller sugar pine.

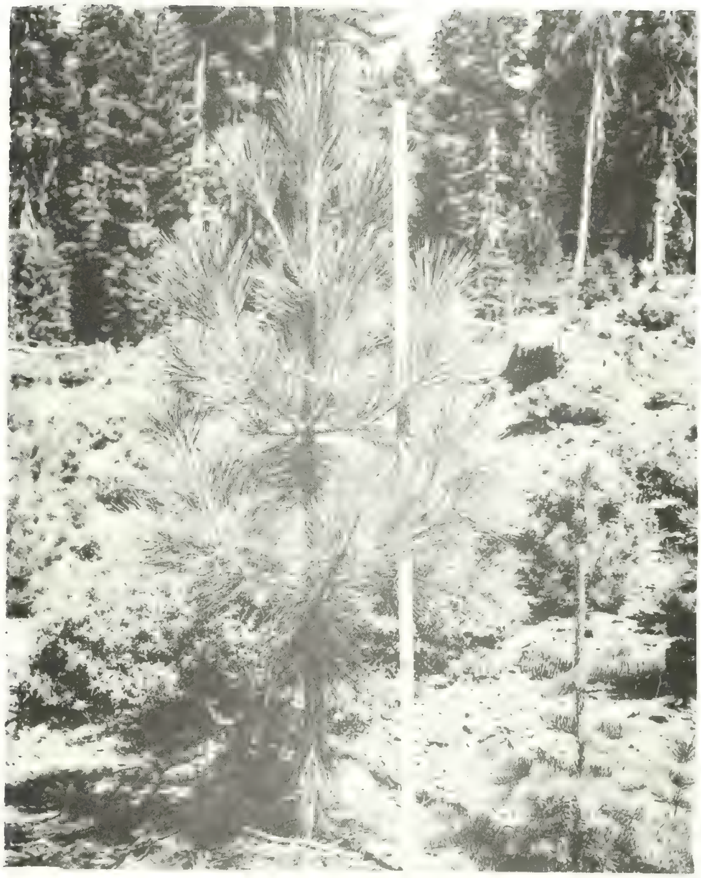

Figure 3.--In the center is a 7-year-old Jeffrey pine almost 7 feet high and in the right foreground is a 7-year-old red fir, Stanislaus Experimental Forest, August 1955.

Conclusions

Differences in mortality and growth rates between white fir and sugar pine in clear-cut openings are of practical silvicultural value. In the management of white fir, clear-cut openings should be avoided where late spring freezes and heavy deer browsing are expected. This is especially true where white fir Christmas trees are to be grown; the damage increases the time required to produce a tree of suitable size and quality. White firs, either for Christmas trees or sawtimber, should be started under partial shade of an overstory. After the trees are well established and the susceptibility to injury is reduced, the overstory may be removed.

In the management of sugar pine, clear-cut openings are recommended for the sugar pine-fir type. The higher survival of sugar pine seedlings increased the proportion of potential sugar pine crop trees in the new stands. The retarding effect of freezing and browsing on white fir height growth favored sugar pine and helped the pine to express early dominance.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 118 February 5, 1957

CALIFORNIA FIRE WEATHER SEVERITY IN 1956

Clive M. Countryman, Forester
Division of Forest Fire Research

The Fire Record

An unusually fine fire record had been hung up by the national forests in northern and central California by the middle of October 1956. Man-caused fires were well below average in number, and the area they had burned was remarkably small (fig. 1). The record put together by the southern California forests was only a little less outstanding at this time: area burned was less than half the previous 5-year average, and man-caused fires were fewer than usual. But in November, a series of fires nearly trebled southern California's burned acreage.

What role did fire weather play in making the good fire records possible in northern California? Can differences in fire weather explain the less favorable record in southern California? What set up the conditions resulting in the November fires there? Fire weather severity indices computed by California national forests can help answer these questions.

The Fire Weather Severity Index--What is it?

As burning conditions become more severe, the fire-control organization is faced not only with larger, faster-spreading fires, but also with the probability that more fires will start.[1] The potential fire load increases at an ever faster rate as fire weather becomes worse.

The California fire danger rating index[2] measures the day-to-day burning conditions and indicates how individual fires will behave. In contrast, the fire weather severity index measures the potential fire load by evaluating the effect of each level of fire danger on number and size of fires. When compiled cumulatively and compared with a standard condition, the severity index shows the relative severity of the fire season at any date.

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[1] Countryman, C. M., and Intorf, P.H. A fire season severity index for California national forests. Calif. Forest & Range Exp. Sta. Misc. Paper 14, 7 pp. 1953.

[2] U.S. Forest Service. 1955 Fire Danger Rating Region 5. 11 pp. plus appendix.

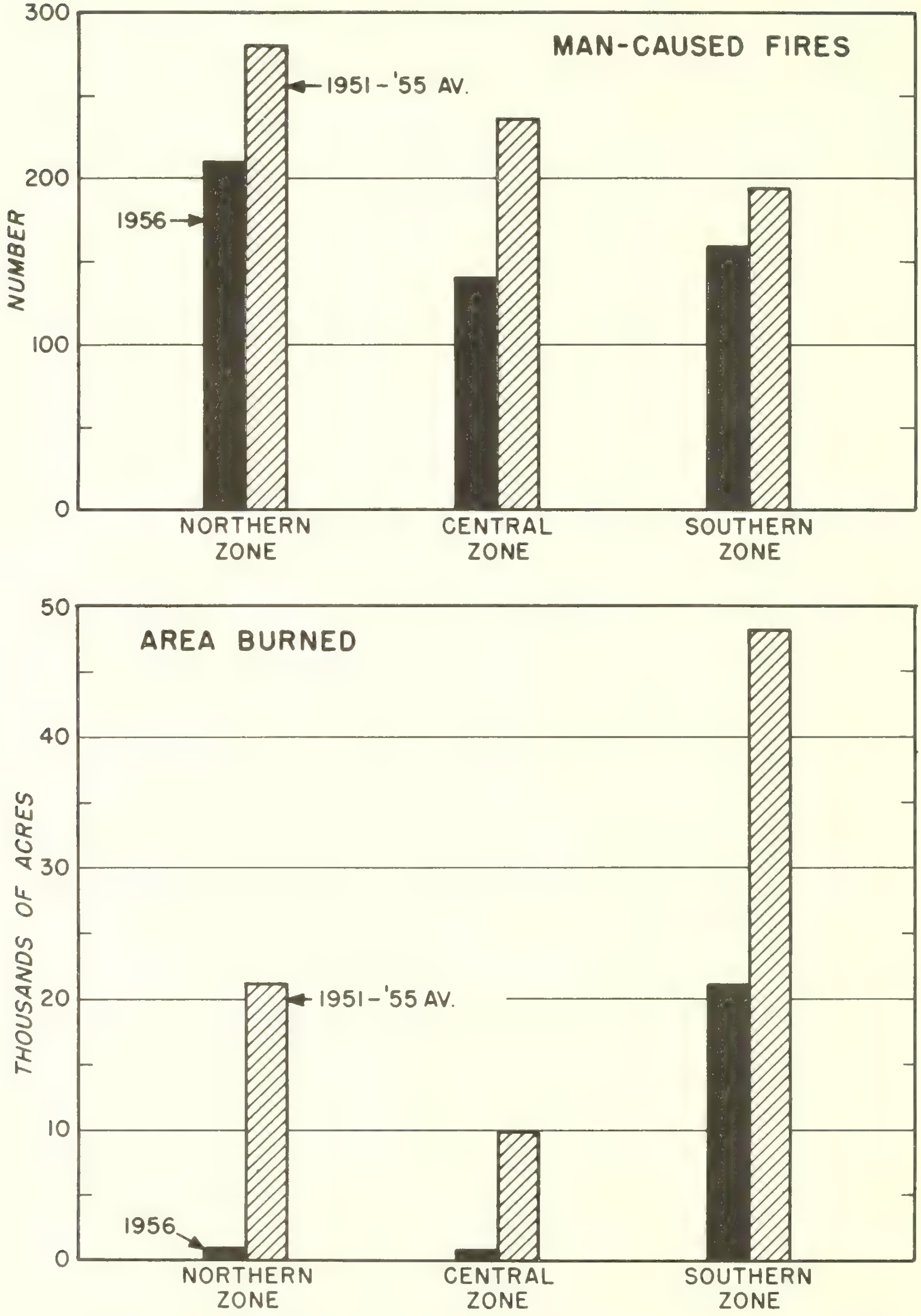

Figure 1. --Number of man-caused fires and area burned in California, 1956. 1951-55 average (January 1-October 15.)

A Regional Severity Index

In California, fire danger ratings are determined daily for individual rating areas into which the national forests have been divided. Direct comparison of these numerical ratings among areas is not possible under the California system. Hence fire weather severity indices derived from the ratings cannot be compared directly. To give a uniform base for comparison, a severity index was computed for each rating area assuming the average fire danger occurred every day. The ratio of the actual severity index to the assumed index was then obtained. These ratios express the fire weather severity relative to that normally experienced for the area--a measure that can be compared directly between areas. The ratios have been grouped into five classes of fire weather severity: low, medium, high, very high and extreme.

For 1956 fire weather severity indices have been computed for the period July 1 to October 15.

The 1956 Fire Weather Severity

Fire weather severity indices for most rating areas in northern and central California fell into the low or medium classes (fig. 2). The "easy" fire weather in these areas is reflected in the relatively small number of man-caused fires and the exceptionally low burned area as compared with the previous 5-year average.

In southern California the fire weather was much more severe. Most of the danger rating areas fell into the high, very high, or extreme classes. Both number of man-caused fires and acres burned were a substantially larger percentage of the 1951-55 average than in northern and central California. The largest fire up to October 15, the McKinley Mountain Fire, San Bernardino National Forest, made up nearly half of the total acreage burned; it occurred in one of the rating areas having an extreme severity index.

Other Uses of the Index

Fire weather severity ratings were used as part of the regional fire danger rating for the first time in 1956. This experience suggests that besides providing a comparison of fire weather season by season, they have two other important uses: during the fire season, the index computed by each rating area can be used to...

...detect a build-up of severe burning conditions

...show how the seasonal trend differs from that during other years.

The record for a northern and a southern forest illustrates the evidence for this conclusion.

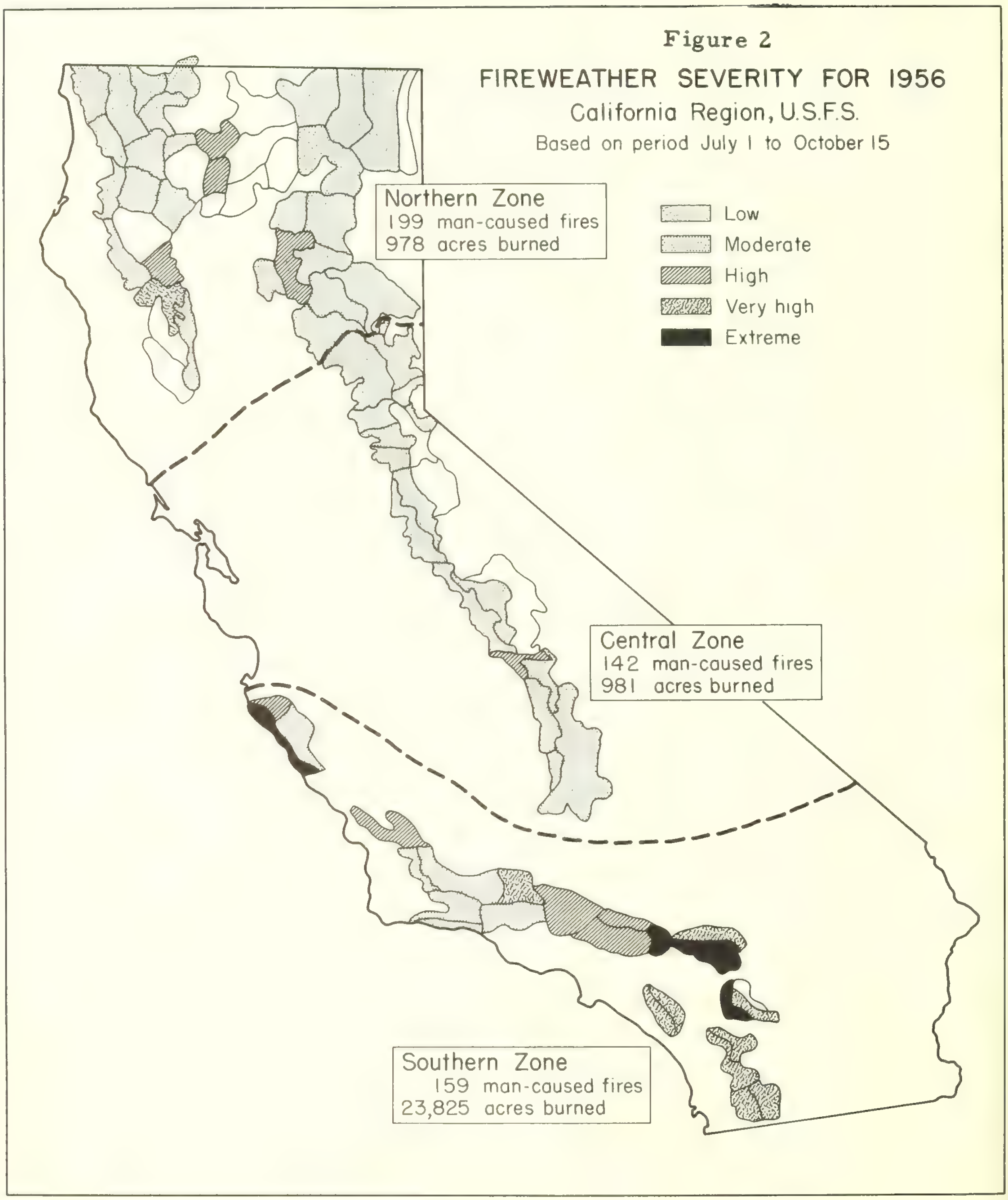

Figure 2

FIREWEATHER SEVERITY FOR 1956

California Region, U.S.F.S.

Based on period July 1 to October 15

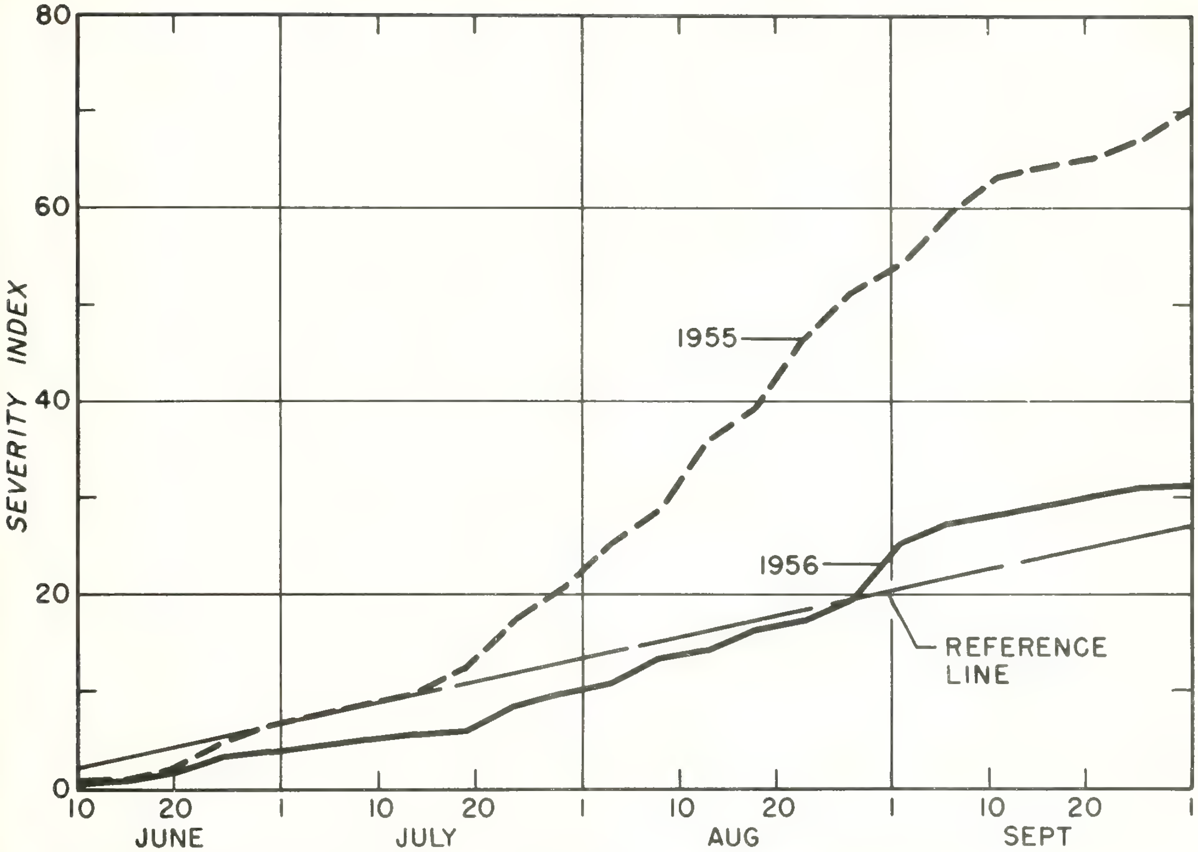

Figure 3.--Fire weather severity, Area 3 Lassen National Forests, 1955 and 1956.

Rating Area 3 on the Lassen National Forest is representative of conditions in northern California. There the cumulated severity indices for 1956, plotted by 5-day periods, are close to a reference line obtained when the average fire danger is assumed to occur every day. The 1956 indices also have about the same slope (fig. 3). This would indicate that the fire danger in 1956 was seldom in the higher classes and there was little tendency for unusual drying conditions to develop.

In contrast the curve for 1955 diverged sharply upward from the reference line after July 15. The steady trend of this curve away from the reference line could be caused only by fire dangers consistently above average. The potential for large fires would become increasingly great as the season progressed under this condition. Preliminary studies of 1955 conditions showed similar curves in other northern California areas.[3] The more than 100,000 acres burned in northern California in 1955 compared with less than 1,000 in 1956 bears out the significance of seasonal severity ratings.

3/ Countryman, Clive M. Fire season severity in 1955 on the Klamath National Forest. For. Res. Note No. 103, Calif. Forest & Range Exp. Sta. 7 pp., illus. 1956.

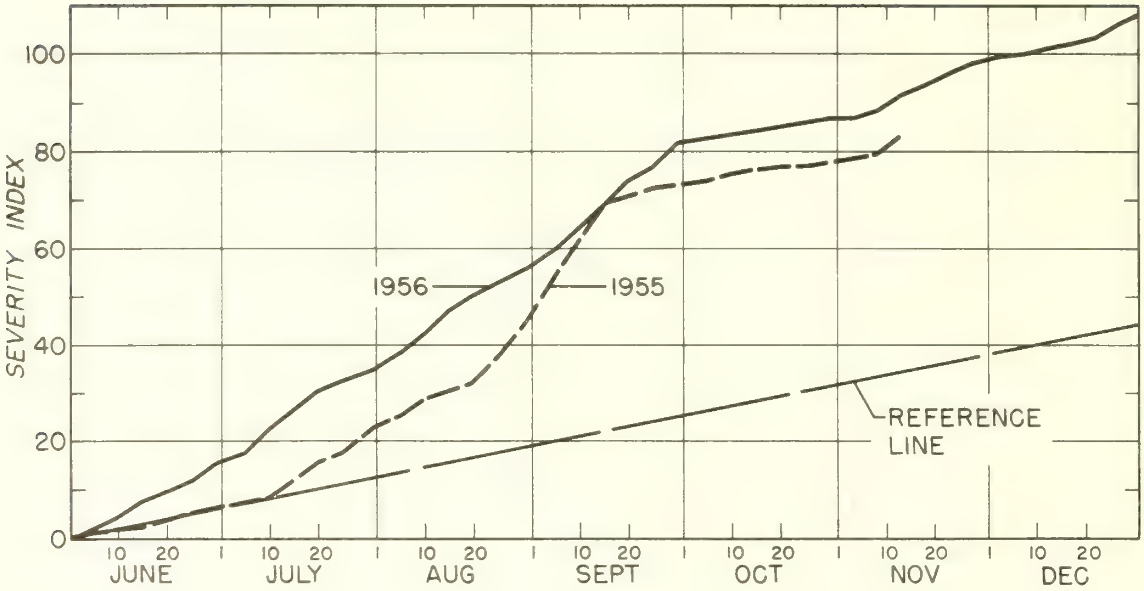

Figure 4.--Fire weather severity on Area 1 of San Bernardino Forest.

Rating Area 1 on the San Bernardino National Forest is representative of conditions in most of southern California. Here the severity index for the entire season up to October 15 was about the same in 1955 as in 1956. Plotted by 5-day periods, however, the cumulative totals show the two seasons to be quite different (fig. 4). The 1955 curve began diverging from the reference line about July 10 but resumed a slope parallel to the reference by September 10. A very sharp rate of increase in the last part of August and first part of September accounted for most of the high index in 1955. Thus the 1955 season was relatively easy except for a short period in which fire danger was unusually high.

In 1956, however, the severity index curve began diverging from the reference line early in the season and continued to climb rapidly to a high level. The extreme dryness brought about by the continual high danger made the potential fire load very great over an extended period of time. We would expect, then, an unusually large number of fires and an excessive burned area in southern California national forests. Unfortunately this potential fire load was confirmed by the fire behavior and control difficulties experienced in the McKinley, East Highland, and Inaja fires.

Conclusion

Originally designed only for comparing severity of seasons, fire weather ratings have demonstrated they also have value in detecting buildup of severe burning conditions. More experience in their use and interpretation undoubtedly will reveal other applications in fire-control planning.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 119 February 15, 1957

"LIGHT BURNING" IN SOUTHERN CALIFORNIA FUELS

Craig C. Chandler, Forester
Division of Forest Fire Research

Light burning has often been suggested as one way to prevent the large and costly fires that periodically scourge southern California. The idea behind "light burning" is to burn the brush during the winter or spring when weather conditions assure easy control of the fire, and thus reduce the quantity of fuel so that a conflagration cannot build up when fire weather is severe.

On the face of it, this idea looks good. Light burning has been suggested and used as a method of hazard reduction. Controlled fire has also been used for years in California to clear brushland for conversion to other types of vegetation. However, southern California's combination of weather, topography, and vegetation is unique. Limited studies of fuel distribution before and after burning indicate that light burning in southern California may increase the fire hazard rather than reduce it.

The Studies

Fuel studies were a routine part of Operation Firestop at Camp Pendleton, California in 1954. Before and after each test fire, samples were taken of the volume, arrangement, and moisture content of all fuels on selected milacre plots.[1] In August and September, fuel was measured on 3 test fires burned when relative humidities were over 30 percent and winds were less than 10 m. p. h. These are considered ideal weather conditions for light burning. All fires were set with drip torches and all were set to burn with the wind.

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[1] Operation Firestop. Fuel studies I. Measurement of fuel bed characteristics of grass and chaparral fuels. 15pp., illus. 1955.

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Results

Under these conditions only sage, the lightest fuel type, burned completely (table 1). Burns in chamise were spotty. Scrub oak, the heaviest brush type, would not carry fire at all.

What did these burns accomplish in the way of hazard reduction? Really very little. Although the sage burned clean, fires in such light fuels are not particularly difficult to control. So light burning of sage only exposed the soil to erosion without making much of a dent in the fire-control job. The spotty chamise burns may increase the hazard by killing some plants without consuming them. Even though the total volume of fuel is reduced in a burn of this kind, the large number of dead, dry plants remaining may actually increase the amount of flash fuels. This can result in hotter, faster-spreading fires than were possible before the light burn. Heavy fuels, such as scrub oak,which are the hardest to control during wild fires, could not be made to burn under weather conditions when safe control could be assured.

Conclusion

These results do not preclude the use of fire for such purposes as building fire lanes and safety islands, or for clearing brush from ridge tops for conversion to less flammable vegetation. However, land managers should recognize that proper use of fire in these situations often requires extensive fuel preparation. They should compare the costs of this type of burning with those of bulldozing, cutting and chipping, or other land-clearing measures. The results do indicate that large-scale light burning in southern California straddles a fine line between twin risks: burns which increase the hazard rather than reducing it, and fires which cannot be controlled.

Results of this limited work also indicate that more intensive studies of brush as a fuel should be undertaken. We need to develop a useful measure of brush flammability in order to explore fully all possibilities for minimizing fire hazard. There is a critical need for intensive fuel studies in southern California.

Table 1. --Dry weight of fuel before and after burning in three types of vegetation, Camp Pendleton, San Diego County, California, 1954

Type	Date	Relative humidity	Wind velocity	Fuel before burning	Fuel after burning	Fuel remaining
		Percent	M.p.h.	Tons/acre	Tons/acre	Percent
Scrub oak	8/12	65	8	40.4	40.4	100
Scrub oak	8/12	65	8	46.8	46.8	100
Sage	9/15	38	5	12.6	0.7	6
Sage	9/15	38	5	13.8	1.3	9
Chamise	9/30	33	7	20.5	3.8	19
Chamise	9/30	33	7	13.0	6.4	49

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 120 February 18, 1957

INSECT-CAUSED DAMAGE TO THE 1956 DOUGLAS-FIR CONE CROP IN CALIFORNIA

Robert E. Stevens, Entomologist,
Division of Forest Insect Research

Insects caused very little damage to northwestern California's 1956 Douglas-fir cone crop. This is the main conclusion drawn from an analysis of cones collected on the Klamath and Six Rivers National Forests. Although the sample was small, it suggests how much damage insects cause in years when the cone crop is good.

Two types of insects cause most of the damage to Douglas-fir cones and seeds. These are the cone moths, mostly belonging to the genera *Barbara*, *Dioryctria*, *Eupithecia*, and *Laspeyresia*, and the seed chalcids, represented by the Douglas-fir seed chalcid, *Megastigmus spermotrophus* Wachtl. Cone moth larvae mine indiscriminately through the maturing cones, destroying axil, scales, and seeds alike. Seed chalcid larvae, on the other hand, remain within individual seeds and feed on the developing embryo.

Sampling

To get a measure of the 1956 insect-caused loss, cones were collected in late August from eight locations throughout the Douglas-fir region. Trees of all sizes bore cones in 1956, and the collection showed no significant difference between percentages of infested cones on large and small trees. At least 50 cones were picked at each location.

The cones were stored indoors until they were examined in December. The analysis was designed to sample both cone moth damage and loss of seed caused by chalcids. Moth damage was determined by examining 50 cones from each lot, the damage being identified by frass, pitch, and holes in the cone scales. Chalcid work was sampled by cutting 500 seeds from each lot. Only the seeds which appeared to be fully developed were selected for this test. Many seeds in the basal part of a Douglas-fir cone never fill up; such seeds were not examined. The seeds were classified as sound, hollow, and infested, and infested seed were identified by the presence of chalcid larvae.

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Results

The samples showed that an average of 16.5 percent of the cones were infested with cone moths, and 0.4 percent of the seeds were destroyed by seed chalcids (table 1). The percentage of the seed lost in a moth-infested cone was not determined. Some midge larvae were found infesting the cones, but they were not numerous enough to cause much damage. Of all the seeds sampled, 16.7 percent were hollow. Some of these hollow seed may have resulted from insect activity, but the possibility was not investigated in this study.

Table 1.--Douglas-fir cones and seeds damaged by insects, samples of 50 cones and 500 seeds from each location, northwestern California, 1956

Location	Moth infested cones	Chalcid infested seed	Hollow seed
	- - - - - - - - - -	Percent	- - - - - - - - - -
No. Haystack Burn	40	0.0	16
So. Haystack Burn	16	0.0	32
Oak Knoll	20	0.8	29
Scott River	4	0.8	22
Seiad Valley	8	1.6	10
Redcap Creek	6	0.2	8
Bluff Creek	34	0.0	8
Willow Creek	4	0.0	9
AVERAGE	16.5	0.4	16.7
STANDARD ERROR	±4.9	±0.26	±4.4
SAMPLING ERROR	30	65	26

FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE – FOREST SERVICE

No. 121

April 1957

WATERSHED MANAGEMENT CONSIDERATIONS FOR SANITATION-SALVAGE LOGGING IN SOUTHERN CALIFORNIA[1]

Walt Hopkins
Division of Watershed Management Research

Southern California's pine forests contain a great many old, overmature trees. The timber manager likes to see these old trees harvested to make room for younger, faster-growing ones. The forest entomologist wants them removed before they create an insect epidemic. Still others favor sanitation-salvage logging because dead and dying trees are a great fire hazard and an ugly sight and even dangerous to the family that goes to the forest for recreation.

What does the watershed manager think about sanitation-salvage logging and watershed management? Does this kind of logging affect our water supply? The situation is something similar to what happens when your house is on fire: The fireman chops a hole in the door to get at the fire and save the house. In sanitation-salvage, we make holes in the watershed cover--we disturb some of the soil--to bring about other benefits.

The watershed manager considers sanitation-salvage logging a help when it is done properly. Probably its greatest benefit is indirect. It helps maintain a healthy stand of trees for watershed cover, and it helps fight fire--one of the worst enemies of the watershed. Cutting high risk trees and snags reduces the fire hazard within the stands and logging roads provide access for fire fighters.

The logger's job, then, is to get the trees out yet disturb the soil and plant cover as little as possible. Some good advice on

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[1] Presented at annual meeting, Southern California Section Society of American Foresters, San Bernardino, December 7, 1956.

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how to do the job has been provided by Cosens[2/] and Briegleb[3/] in their work in the Sierra Nevada and the Pacific Northwest. McRorey, Meadowcroft and Kraebel[4/] published a guide on this subject, and the timber management staffs on the southern California national forests, considering the varied interests at stake, have spelled out several essentials basic to good watershed management.

All these workers found that a successful logging job hinges on effective advance planning. The forester and the logger should carefully work out a logging plan--plans for roads, skid trails, and landings--before sanitation-salvage logging actually starts. Then they can efficiently and easily coordinate forestry and logging phases of the operation; they won't have to improvise and go back and adjust road and landing locations after logging begins. Another thing about advance planning: It helps you drive home to the loggers the watershed values at stake. This is of great importance. The men in the woods must understand that their job is to reduce damage to the watershed as well as to get out the logs.

What does this advance planning accomplish? A more efficient operation and less wear and tear on the watershed.

Aerial photos, especially when used in stereo, and a topog map are a big help in selecting tentative locations for roads, landings, turn-arounds, and the area to be served by each landing. Then when the forester and logger scout the area, they can mark the final locations on a map on the ground.

Much stream siltation can be avoided by proper road location. Roads placed back from live or intermittent streams keep dirt from construction out of the channel. Where this is not possible--as at stream crossings--water level crossings (stabilized dips), temporary bridges, or other drainage structures help prevent interference with the flow of the stream.

In steep terrain, use of a dry channel for a short distance may result in less soil movement than grading a tractor road on the slopes, but be sure to re-grade the channel and clear it of slash after logging to permit full streamflow in the wet season. No logs

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2/ Cosens, R. D. Reducing logging damage, Calif. Forest and Range Expt. Sta. Research Note 82. 10 pp., illus. 1952.

3/ Briegleb, Philip A. Applied forest management in the Douglas-fir region, Pacific Northwest Forest and Range Expt. Sta. Research Note 71. 9 pp. 1950.

4/ McRorey, R. P., Meadowcroft, N. F., and Kraebel, C. J. A guide to erosion reduction on national forest timber sale areas. California Region, Forest Service, U. S. Dept. Agri. 78 pp., illus.

or chunks should be left in a gulch bottom in such a position that the channel will be plugged or that water will be diverted against either bank; otherwise, the diverted stream can erode the toe of the slope or cause waterfalls to gouge out the channel bottom.

Keep the amount of earth moved in road construction to a minimum. Frequently, the amount of cutting and filling necessary can be greatly reduced by laying out a slightly rolling grade instead of a sustained grade, without significantly reducing the traffic-carrying capacity of the road. An undulating road will also divert runoff every now and then and thus reduce erosion of ditches and roadbeds. Care and good timing in building roads can prevent much soil from moving into waterways. Construction during dry periods not only causes less erosion, but as every logger knows, is cheaper. During periods of heavy runoff, assign a man with a shovel to divert streams of water that run over the roadway. This will avoid a great deal of sedimentation from road construction, and should be continued after the road is in use--until the surfaces are hard and safe and new drainage patterns are well stabilized.

Plan skid-trail locations before logging with four main objectives. First, make the trails service the entire landing area so there will be no call for additional trails at the time of logging. Second, keep the number of trails to a minimum, with branch trails joining the main ones as soon as feasible. The less trail you build, the less erosion and the less the logging job costs. Third, keep channel crossings to a minimum. For example, good management can call for two landings located relatively close together--one on the north side of the stream and the other on the south side. Locate trails as far away from the stream edge as practicable in order to minimize disturbances on or near stream banks. Fourth, locate the trails to avoid long or steep adverse grades, unnecessary distances, and sharp turns. Confine skidding to these trails except for the actual pick-up of logs.

Locate landings in natural, level openings and on firm dry ground whenever possible. In moderate terrain this is easily attained; in steep country careful designation of landing sites is necessary to minimize watershed damage. Often you can make landings by widening the haul roads at some distance from water courses. Cribbing built with cull or unmerchantable logs and chunks on the downhill side will support a landing fill and thus minimize excavation.

Fell the trees away from drainage channels to keep the slash out of waterways. Limb the logs before yarding. Be sure the loggers know the location of the skid trails. Then, they can place the trees so that yarding crews can roll and skid the logs with a minimum amount of soil disturbance.

Slash disposal is often considered solely as a method of reducing fire hazard. Don't overlook the opportunity, however, for using slash from tops and other debris to minimize or prevent erosion damage. Slash and litter properly placed in skid trails will lessen soil movement and divert excess water out of trails; improperly placed, it is ineffective, wasteful of effort, and may even increase erosion. Place the material in good contact with the soil and the larger pieces at such angles that they will lead water out of the skidway at frequent intervals. Portable chippers, now in use on two of the southern California national forests, will chip slash and blow a mulch into old skid trails and other bare and unstable areas. In general, the combination of good road location, well-placed waterbreaks, and slash placement in critical spots, will provide effective erosion protection.

Good road location with an eye to the future usually means easier maintenance. Primary roads built by the logger and maintained after logging make more recreation areas available and serve as fire access roads. Temporary roads, tractor roads, and trails should be "put to bed" at the end of the season so that water will not rush down the ruts. Blade off the berm, remove temporary fills, and install water bars in the roadways at intervals so that water will be led off and spread over undisturbed soil before it can attain enough volume and velocity to cause serious erosion.

At present most of the southern California sanitation-salvage logging areas are on the less critical slopes and on rather deep, fairly stable soils. On the steeper, more erosible slopes, logging cannot be tolerated unless it can be conducted with little or no soil disturbance. This may become possible, however, through some adaptation of a gravity cableway system.

Now, to summarize the main considerations:

1. Carefully plan roads, skid trails, and landings before logging is started.
2. Be sure the loggers understand the watershed values at stake.
3. Locate roads and trails away from stream channels.
4. Keep earth moving to a minimum. Keep road and trail mileage as low as possible.
5. Keep channel crossings to a minimum.
6. Avoid long or steep grades.
7. And after logging, put temporary roads and trails "to bed" and place slash and litter so that runoff velocities and soil movement are kept to a minimum.

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FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR

U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 122 May 7, 1957

ETHYLENE DIBROMIDE EMULSION SPRAY FOR CONTROL OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

By Robert E. Stevens, Entomologist,
Division of Forest Insect Research

A water emulsion spray of ethylene dibromide has been found effective for control of the mountain pine beetle in lodgepole pine. This spray was developed for use against the Engelmann spruce beetle in Colorado[1] and can probably be used against most bark-beetle species in thin-barked trees. For thick-barked trees, an oil spray of ethylene dibromide is used.[2]

Spraying is the preferred control method when fire danger is high, and an emulsion is often preferable to an oil spray. The main advantage of the emulsion spray is that 80 percent of its volume is water, which can usually be obtained in the woods close to the treating site. Therefore, much less material has to be carried into the woods, and transportation costs are often materially reduced. An additional benefit is that emulsions are less disagreeable to work with than oil sprays.

The spray consists of water and fuel oil, to which an emulsifier has been added so the two will mix, and the insecticide--liquid 85 percent ethylene dibromide.

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[1] Massey, C. L., Chisholm, R. D., and Wygant, N. D. 1953. Chemical control of the Engelmann spruce beetle in Colorado. Econ. Ent. 46(6):951-955.

[2] Downing, G. L. 1954. Ethylene dibromide sprays for controlling bark beetles in California. Misc. Paper No. 17, Calif. Forest and Range Expt. Sta. 2 pp.

Equipment and Materials

Aside from saws, axes, peavies, etc., necessary for handling the trees, the following equipment and materials are needed, in quantities depending on the size of the job:

1. Fifty-five gallon drums, for mixing emulsifiable concentrate.

2. Five-gallon cans, for transporting concentrate and finished spray.

3. Gallon cans with handles and spouts, for measuring emulsifiers, insecticide, and concentrate.

4. Garden-type sprinkling cans, for applying the spray. Under some circumstances, power spraying equipment such as a Bean slip-on unit may be useful. Care must be taken to use low pressures, however, to avoid bouncing spray off the logs and creating a mist, which usually drifts away.

5. Ethylene dibromide (85 percent).

6. Emulsifier (Triton X-100 and Triton B-1956).

7. Diesel oil.

Procedure

Treating consists of three steps: Preparing the trees, preparing the spray, and spraying.

Preparing the trees.--Fall and limb the tree, and buck the infested part of the trunk into lengths that can be rolled.

Preparing the spray.--This involves two main steps--preparing the emulsifiable concentrate at the base camp, and mixing it with water, usually at the treating area. The concentrate consists of ethylene dibromide, fuel oil, and an emulsifier. For the emulsifier, mix 3 parts Triton X-100 with 5 parts Triton B-1956. Then mix 3 parts of the emulsifier with 5 parts 85 percent ethylene dibromide and 24 parts diesel oil. This is the material taken into the woods. At the treating area, mix 1 part of the concentrate with 4 parts of water. Pour the concentrate in first, and make sure the finished spray is well mixed.

Spraying.--Using a sprinkling can, drench the top of each log until the spray just begins to run off. Let it soak into the bark, then roll the log so that an untreated area is on top, and repeat. Continue until the entire bark surface has been covered--this usually requires 2 or 3 turns of the log. Do not treat when the bark is wet. Be sure to get total coverage--beetles under untreated bark will not be killed.

An average of about 8 gallons of finished spray will be needed to treat a lodgepole pine 36 inches in diameter at breast height. At current prices, the spray will cost about $0.27 per gallon.

Sources of Supply

Ethylene dibromide (85 percent) can be obtained from most agricultural chemical suppliers. Triton X-100 and Triton B-1956 are available from Rohm and Haas Co., 600 California Street, San Francisco, Calif.

CAUTION: Ethylene dibromide and diesel oil are skin irritants. Any material spilled on the skin or clothing should be washed off immediately with soap and water. The concentrate has the flammability of diesel oil and the usual precautions should be observed when handling it. Avoid breathing the fumes of ethylene dibromide.

Note: In order that the information in our publications may be more intelligible, it is sometimes necessary to use trade names of products or equipment rather than complicated descriptive or chemical identifications. In so doing it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M JEMISON, DIRECTOR
U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 124 May 1957

A RECORD OF TANOAK ACORN AND SEEDLING PRODUCTION IN NORTHWESTERN CALIFORNIA

D. F. ROY, Forester,
Division of Forest Management Research

Tanoak (Lithocarpus densiflorus (Hook. and Arn.) Rehd.) is an aggressive hardwood which attains maximum development in Humboldt and Mendocino Counties, California. A common associate of commercial conifers, it assumes two forms in virgin forests. Tanoaks may be tall trees with straight trunks which are clear of limbs for 30 to 80 feet. Or they may form shrubby undergrowth which endures remarkably well in the shade.

When the conifers are harvested, tanoak shrubs respond to release after logging and often dominate an entire cutover. And if logging or slash fires destroy the aerial parts of either trees or shrubs, the vigorous root systems produce new fast-growing sprouts. 1/

Are residual tanoak trees also able to establish new trees by seeding-in cutover ground? The purpose of this study was to find answers to these questions.

The Study

The study consisted of two parts. First, we collected acorns and examined them to learn something about seed abundance and quality. Second, we counted and measured tanoak seedlings to find how many the acorn crop produced and how fast they grew.

Eight tanoaks growing on the Brush Mountain Unit, Six Rivers National Forest, near Salyer, California, were chosen for the study. These trees varied from 18 to 26 inches in diameter. They were growing on soil more than 3 feet deep which was classified as Hugo clayey loam.

1/ Roy, D. F. Hardwood sprout measurements in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 95, 6 pp., illus. 1955.

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The ground sloped toward the east at an average rate of 40 percent, and the elevation ranged between 2,400 and 2,500 feet. Logging of the Douglas-fir stand in 1952 had prepared seedbeds of loose mineral soil.

The Acorn Crop

We knew that tanoaks produce abundant seed crops. Trees are heavily laden almost every other year, and complete seed crop failures are rare. However, insects destroy many acorns. To estimate the amount of sound tanoak acorns, we collected samples from the ground under three trees chosen without prejudice from the eight tanoaks selected for the study. The acorns were gathered November 14, 1953.

We sampled quantity by selecting ten 1-foot square areas at random under each tree and counting the acorns lying on the ground within these areas. Sampling was restricted to a circular area 1/20th of an acre in size (radius equal to 26.3 feet) because the heavy acorns fall straight to the ground and most remain under the crown of the tree. Acorns were collected at rates from 78,408 to 91,476 per acre--an average of 84,216 per acre (table 1).

To get some idea of the quality of tanoak acorns, we collected additional samples from the ground under the same trees where the quantity of seedfall was sampled. Examination of the acorns showed that insects destroyed a significant amount--51 percent of all acorns collected (table 2).

The acorns were stored about 2 weeks before they could be examined. During this period coleopterous and lepidopterous larvae emerged from them. Several larvae were given to the entomologists 2/ who attempted to rear adults which could be positively identified. One adult beetle, the filbert weevil (*Curculio uniformis* (Lec.)), emerged in the rearing cages. Two moths matured. They were the filbertworm (*Melissopus latiferreanus* (Wlsm.)), and a grey moth similar to *Valentinia glanulella* (Riley) which was tentatively identified as *Holcocera* sp. An adult ichneumon fly (*Pimplopterus dakrumae* (Ashm.)), which is probably an insect parasite rather than an acorn pest, also emerged.

Tanoak Seedlings

To find how effectively the tanoak acorn crop produced seedlings, we counted the seedlings on a 1/20th-acre plot under each of

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2/ Division of Forest Insect Research, Calif. Forest and Range Expt. Sta.

Table 1.--Number of acorns under tanoak trees, Brush Mountain Unit, Six Rivers National Forest, near Salyer, California, 1953

Sample number	Acorns found on square foot samples		
	Tree 1	Tree 4	Tree 6
	Number		
1	1	1	5
2	2	4	1
3	5	6	0
4	0	0	3
5	3	3	1
6	4	1	2
7	0	3	2
8	2	0	1
9	0	1	0
10	2	2	3
Total	19	21	18
Number per acre under trees	82,764	91,476	78,408
D.b.h.-inches	18.3	22.2	23.9

Table 2.--Tanoak acorns destroyed by insects, Brush Mountain Unit, Six Rivers National Forest, near Salyer, California, 1953

Tree number	D.b.h.	Acorns collected	Acorns destroyed by insects	
	Inches	Number	Number	Percent
1	18.3	240	65	27
4	22.2	250	206	82
6	23.9	347	153	44
All	--	837	424	51

the 5 tanoaks from which the seed crop was not sampled the preceding fall. Since tanoak germination is hypogeous, the small trees were pulled from the soil to make sure they were really seedlings and not root sprouts. Heights from the cotyledons to the growing tips also were measured. The seedlings were counted and measured July 22, 1954.

The numbers of seedlings found on 1/20th-acre plots varied between 8 and 19, and averaged 13, or an average of 264 seedlings per acre (table 3).

The efficiency of the crop of sound acorns in producing seedlings was low. It was calculated by dividing the average number of seedlings per acre by the average number of sound acorns falling per acre:

$$\frac{264}{84{,}216 \times .49} = 0.64 \text{ percent}$$

Biotic factors may have contributed to the low seed crop efficiency. We know several birds and mammals eat tanoak acorns: The California woodpecker (*Balanosphyra formicivora bairdi* (Ridgway)), band-tailed pigeon (*Columba fasciata fasciata* Say), blue-fronted jay (*Cyanocitta stelleri frontalis* (Ridgway)), Pacific varied thrush (*Ixoreus naevius naevius* (Gmelin)), Townsend chipmunk (*Eutamias townsendii* Bachman), dusky-footed wood rat (*Neotoma fuscipes fuscipes* Baird), Douglas ground squirrel (*Otospermophilus grammurus douglasii* (Richardson)), redwood chickaree (*Sciurus douglasii mollipilosus* (Audubon & Bachman)), California gray squirrel (*Sciurus griseus griseus* Ord.), American black bear (*Euarctos americanus americanus* (Pallas)), and Columbian black-tailed deer (*Odocoileus hemionus columbianus* (Richardson)). 3/ Low germinative capacity also may have been a factor. A germinative capacity as low as 19 percent has been reported for tanoak acorns. 4/

The height of the tanoak seedlings, measured from cotyledons to growing tip, varied from 1.9 to 8.3 inches, and averaged 5.2 inches. Since we measured the trees on July 22, total first-year growth might have been more. Even the heights in July, however, were greater than first-year height growth of conifers on the same site. All tanoak seedlings were vigorous (fig. 1).

3/ Letters from Lloyd P. Tevis, Jr., dated February 13, 1957, and Donald C. Hagar, Jr., dated February 26, 1957.

4/ U. S. Forest Service. Woody plant seed manual. U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus. 1948.

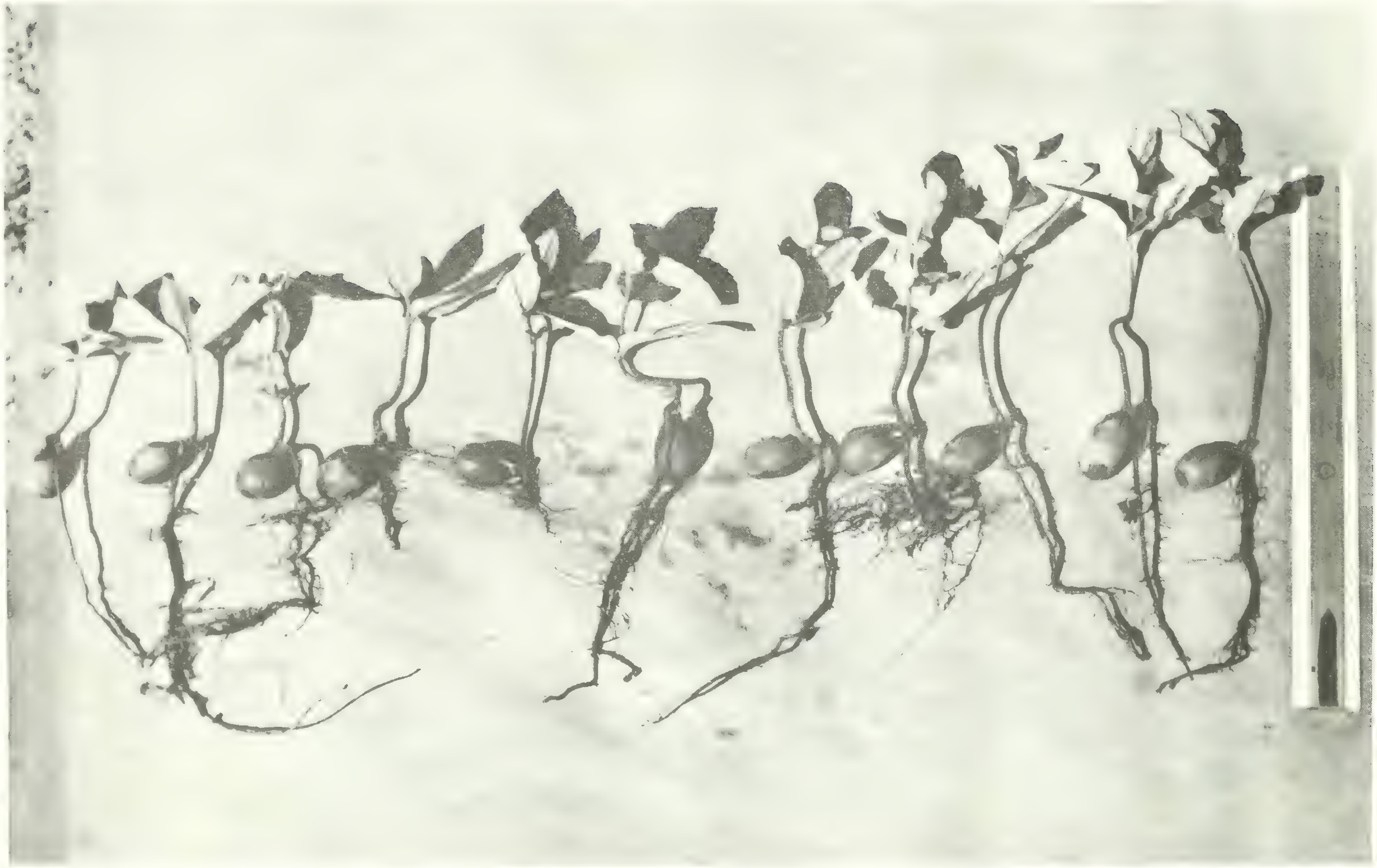

Figure 1.--Tanoak seedlings collected from a 1/20th-acre plot under a tanoak tree 19.5 inches in diameter breast height. By July 22 these seedlings ranged in height from 2.1 to 6.8 inches, and averaged 4.4 inches tall. Brush Mountain Unit, Six Rivers National Forest, near Salyer, California, 1954.

Table 3.--Number and heights of tanoak seedlings from 1953 acorn crop, 1/20th-acre plots, Brush Mountain Unit, Six Rivers National Forest, near Salyer, California, July 22, 1954

Tree number	D.b.h.	Seedlings		Heights of Seedlings	
		Per plot	Per acre	Range	Average
	Inches	- - - Number - - -		- - - Inches - - -	
2	23.5	12	240	2.9--8.3	5.5
3	19.5	11	220	2.1--6.8	4.4
5	24.7	16	320	2.7--7.1	5.1
7	26.4	19	380	1.9--7.9	6.1
8	20.3	8	160	2.0--6.6	4.0
All	22.9	13	264	1.9--8.3	5.2

Summary and Conclusions

Tanoak acorns were collected and examined to learn about amount and quality of seedfall. The number of acorns found under tanoak trees from 18 to 24 inches in diameter at breast height averaged 84,216 per acre. Of these, 51 percent were destroyed by insects, leaving 41,266 sound acorns per acre.

The acorn crop, although only 0.64 percent efficient, established seedlings at the rate of 264 per acre. By July of the first growing season heights of the tanoak seedlings ranged from 1.9 to 8.3 inches, and averaged 5.2 inches. All tanoak seedlings were vigorous.

We conclude that residual tanoaks produce seedlings capable of controlling forest land. Although the 1953 acorn crop did not produce seedlings efficiently, some were established. Since tanoaks consistently produce acorn crops, we can expect more seedlings each year. Because young tanoaks grow vigorously, they might capture the ground under parent trees, especially if Douglas-fir seed crops fail. The amount of ground captured by tanoak seedlings will depend upon the number of tanoaks left after logging.

FOREST RESEARCH NOTES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR
U.S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

No. 126 August 1957

CALIFORNIA CONE CROP--1957

Gilbert H. Schubert, Forester,
Division of Forest Management Research

California forest trees are expected to produce a good cone crop in only a few localities this year. Generally the crop is rated as none or very light. A medium or heavy crop is indicated in some seed zones; however, even in these zones the crop will vary greatly in different parts.

These are the main conclusions from a study of the cone-crop reports sent to the California Forest and Range Experiment Station by members of the California Division of Forestry, the California Region of the U. S. Forest Service, and the Southern California Edison Company.

The reports were generally based on occular estimates in which the crop was rated as none, very light, light, medium, or heavy, according to the cone crop classification used in Oregon. [1] In this classification the cone crop ratings are:

1. None--no cones on any trees or few cones on occasional trees.

2. Very light--few cones on 25 percent of the trees, or few cones on 25 percent of the trees and many cones on occasional trees.

3. Light--few cones on 75 percent of the trees, or many cones on some trees and few cones on 75 percent of the trees.

4. Medium--some cones on all trees, or many cones on less than 75 percent of the trees.

5. Heavy--many cones on 75 percent of the trees and some cones on all trees, or many cones on all trees.

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[1] Engstrom, W. H. Oregon cone crop, 1954. Oregon State Board of Forestry. Res. Note 16, 7 pp., 1954.

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Although these ratings are subjective, they provide valuable information for those planning to collect seed this fall.

As an aid to seed collectors, the crop reports have been segregated according to the forest tree seed collection zones described by Fowells. [2] This grouping (table 1), showed that the most promising localities for collecting seed of major commercial conifers--those with medium to heavy cone crops--were as follows:

	Seed Zone
Incense-cedar	III and IX
Douglas-fir	III and X
Red fir	II, III, V, VII, VIII, and XI
White fir	I, V, and VIII
Jeffrey pine	I, V, IX, and X
Ponderosa pine	I and IX
Sugar pine	IV and V

A map of the collection zones is appended to this note, but since the seed crop is spotty and varies widely in most zones, it is also advisable to consult field offices of the California Division of Forestry or the U. S. Forest Service to determine best areas to collect cones.

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[2] Fowells, H. A. Forest tree seed collection zones in California. Calif. Forest and Range Expt. Sta. Res. Note 51, 5 pp., illus. 1946.

Table 1.--Summary of cone crops by species and seed zone, California, 1957

Species	Seed collection zone or county	Cone crop [1]
CEDAR:		
Incense-cedar (*Libocedrus decurrens*)	I, VIII, X	None
	II, VII	None to very light
	IV, V	None to light
	III, IX	None to medium
DOUGLAS-FIR:		
Bigcone Douglas-fir (*Pseudotsuga macrocarpa*)	IX	Very light to light
Douglas-fir (*P. menziesii*)	IV, VIII, XII, Lake and Napa	None
	I, II, XIII	None to very light
	V, XI	None to light
	III, X	None to medium
FIR:		
Bristlecone fir (*Abies bracteata*)	XIII	Very light
California red fir (*A. magnifica*)	I, X	None to light
	II, III, V, VII, XI	None to medium
	VIII	None to heavy
Lowland white fir (*A. grandis*)	XI, XII, XIII	None
White fir (*A. concolor*)	VII, IX	None to very light
	II, III, IV, X, XI	None to light
	I, V, VIII	None to medium
PINE:		
Bishop pine (*Pinus muricata*)	X, XII	Very light
	XIII	Light to medium
Coulter pine (*P. coulteri*)	XIII	None to medium
	IX	Very light to medium

Species	Seed collection zone or county	Cone crop [1]
PINE: (continued)		
Jeffrey pine (*P. jeffreyi*)	XI	None
	II, VIII	None to very light
	III, IV, VII, XIII	None to light
	I, V, IX, X	None to medium
Knobcone pine (*P. attenuata*)	IX, X, XI, XIII	Light to medium
	I, III	Medium to heavy
Lodgepole pine (*P. contorta*)	V	None
	XII	None to very light
	I, VI, VII	Light to medium
	XIII	Medium
Monterey pine (*P. radiata*)	XIII	Heavy
Ponderosa pine (*P. ponderosa*)	XI, XIII, Lake and Napa	None
	VIII, X	None to very light
	II, III, IV, V	None to light
	I, IX	None to medium
Sugar pine (*P. lambertiana*)	VIII, IX, XI,XIII, Lake, Napa	None
	II	None to very light
	I, III, VII, X	None to light
	IV	None to medium
	V	None to heavy
Western white pine (*P. monticola*)	I, VII, VIII	None to medium
SEQUOIA:		
Giant sequoia (*Sequoia gigantea*)	IV	Very light
	V	Very light to medium
Redwood (*S. sempervirens*)	XII	Light
	XIII	Very light to medium

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[1] Reported by technicians of the California Division of Forestry, the California Region of the U. S. Forest Service, the California Forest and Range Experiment Station, and the Southern California Edison Company.

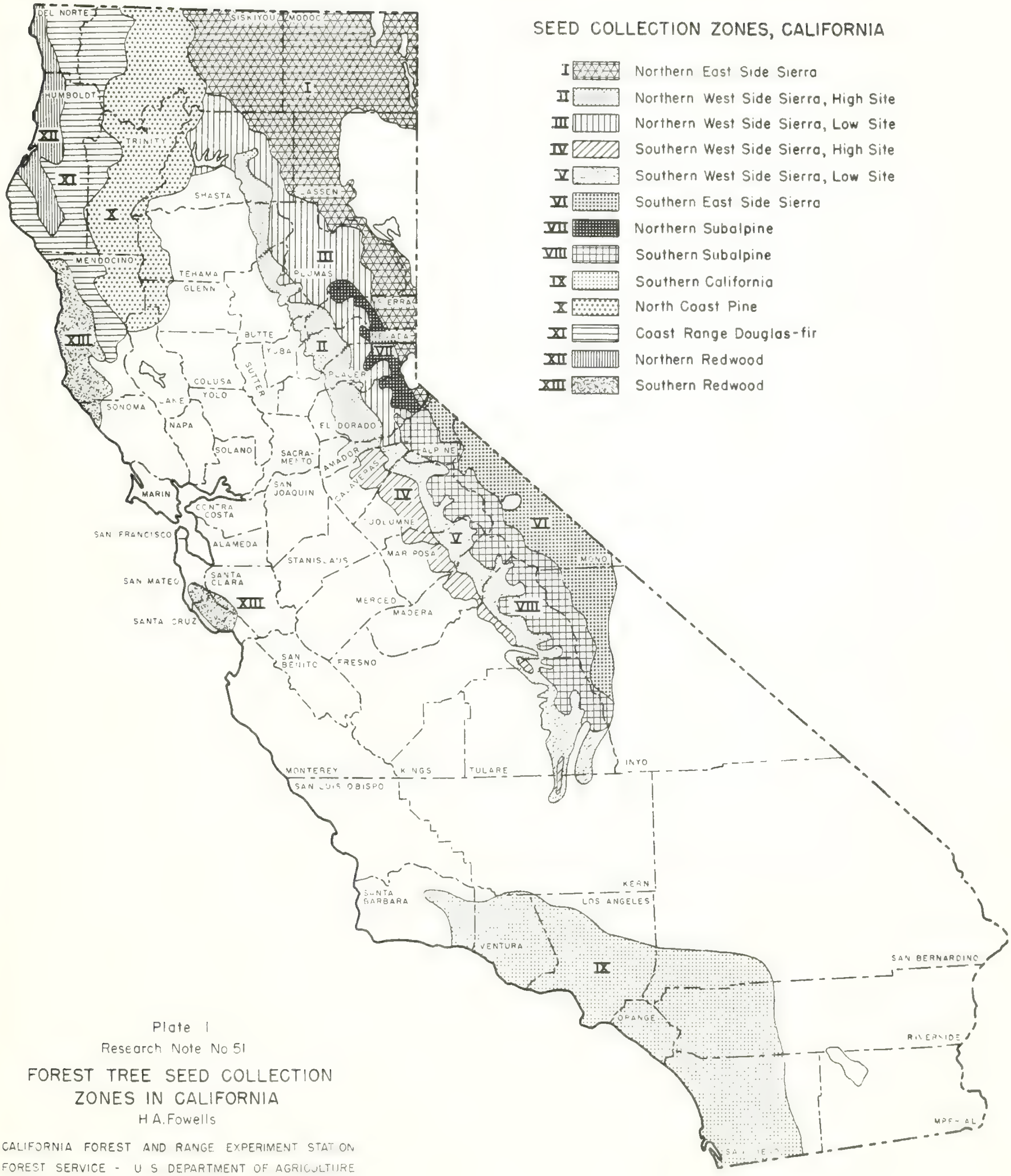

Plate I

Research Note No 51

FOREST TREE SEED COLLECTION ZONES IN CALIFORNIA

H A. Fowells

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE - U S DEPARTMENT OF AGRICULTURE

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